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# Public Visualization: Engaging Citizens with Data through Situated Public Displays

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## Abstract

Driven by a global movement towards transparent governance, an increasing number of cities are opening up their data. Aside from the obvious economic possibilities, this data also offers citizens the possibility to understand the urban context, to gain insights on civic opportunities and challenges, or to organize debates on civic issues. However, if this data is expected to reach a wide variety of citizens, the visualizations should fit into the existing communicative ecology of cities. In this thesis, we present the concept of public visualization, which brings data in an opportunistic way to citizens by situating data at the actual location of its capturing, thereby allowing social interactions and fostering civic engagement. Through a series of in-the-wild studies, in which visualization prototypes are deployed in the real world, we explore how design aspects of the content of public visualization, its carrying artifact and the surrounding environment affect insight generation.

* In *Street Infographics,* a guerrilla-style intervention that augmented actual street signage with statistic information, we explored the effect of spatially contextualizing public visualizations on user engagement and insight generation;

* In *Sight on Local Data*, a physical see-through artifact placed in a public street, we studied the influence of tangible versus touch interaction on how people engage with public visualization;

* In *Bicycle Barometer,* a cyclist-specific public polling display, we investigated how contextual elements such as location, material qualities and interaction design aspects affect participation rate.

* In *Narrative Visualization*, a visualization shown on a public touch-enabled display, we evaluated how narrative annotations integrated in public visualization affects insight generation.

* In *Data on Site,* a public visualization toolkit for spatial distribution is deployed to raise awareness on the issue of air pollution, which we evaluated in different neighborhood contexts.

In summary, this dissertation contributes to the understanding of public visualization as a means to create awareness and reflection on local and civic issues, to elicit social discussion and to trigger considerate civic responses, thereby demonstrating how data-driven and well-situated technological interventions in public space can support the involvement of citizens in civic debates.

## Samenvatting (Nederlands)

De wereldwijde tendens om de werking van de overheden meer transparant te maken, drijft ook meer en meer steden om hun data 'open' te maken. Behalve de meer voor de handliggende economische mogelijkheden die door open data gecreëerd worden, bezorgen deze data burgers ook de mogelijkheid om hun directe omgeving beter te begrijpen, inzichten te verkrijgen over de stedelijke uitdagingen en opportuniteiten, of om debat te organiseren rond stedelijke vraagstukken. Als er echter verwacht wordt dat deze data een brede doelgroep van burgers bereiken, dan moeten de visualisaties ook passen in de bestaande communicatietaal van de steden. In deze thesis presenteren we het concept van publieke visualisatie om data op een opportunistische manier naar burgers te brengen door data te situeren op de eigenlijke locatie van captatie, en daarbij het vormen van sociale interacties en voeden van burgerengagement toe te laten. Door middel van een serie case studies *in-the-wild,* waarbij visualisatie prototypes worden ingezet in de echte wereld, verkennen we hoe design aspecten van het onderwerp van de publieke visualisatie, zijn drager en de nabije omgeving, het genereren van inzichten toelaat.

* In *Street Infographics*, een interventie die bestaande straatnaamborden versterkte met demografische informatie, verkenden we het effect van ruimtelijke, gecontextualiseerde publieke visualisaties op het engagement en het genereren van inzichten;

* In *Sight on Local Data*, waarbij de drager geïnspireerd werd op een telescoop, bestudeerden we de invloed van tastbare en aanraakbare interactie op hoe burgers engageren met publieke visualisatie;

* In *Bicycle Barometer,* een interactieve stembus op maat van fietsers, evalueerden we hoe contextuele elementen zoals locatie, materiaal en de specifieke eigenschappen van de gebruikers, de deelnameration kan beïnvloeden;

* In *Narrative Visualization,* een touch screen opstelling in een openbare bibliotheek, onderzochten we hoe narratieve annotaties die de inhoud van een publieke visualisatie versterken, het genereren van inzichten kan beïnvloeden;

* In Data on Site, een toolkit om publieke visualisaties over de publieke ruimte te verspreiden, evalueerden we de invloed van de nabije omgeving op engagement en het genereren van inzichten.

Deze thesis draagt bij tot het begrip van het inzitten van publieke visualisaties als een middel om bewustzijn en reflectie over lokale en stedelijke vraagstukken te creëren, om sociale discussies uit te lokken en om bedachtzame antwoorden te formuleren. Daarbij demonstreert deze thesis hoe data-gedreven en goed-gesitueerde technologische interventies in de publieke ruimte de betrokken van burgers in het stedelijk debat kan ondersteunen.

## Acknowledgements

Ten years ago I was mainly active as a designer of audiovisual and interactive media. Today, I am both designer and researcher. The trajectory from designer to design researcher was a true rollercoaster. This ride was so challenging yet fascinating and inspiring, for which I owe much gratitude to my supervisor, Andrew Vande Moere. Andrew, thank you for giving me the opportunity and believing in my skills, for transferring research skills without 'teaching', for being high demanding, pushing boundaries but being compassionate (yes, even human) at the right times. I really appreciate your direct style and advice, on research topics but also on my design work, future work directions and even on dietary topics (I still use your recipe for bread).

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Thank you, Wald and Len. We will continue the prototyping sessions.

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## 1. Setting the scene

Cities are increasingly interwoven with smart technologies that capture public data to monitor processes of corporate and civic institutions (Harding, Knowles, Davies and Rouncefield, 2015; Balestrini, Rogers, Hassan, Creus, King and Marshall, 2017). Parking, cycling and pedestrian behaviors, for instance, are tracked by city councils to inform urban planning processes. Also grassroots initiatives of citizens are increasingly deploying data monitoring devices to keep track and collect evidence on local issues and concerns (Thomas, Wang, Mullagh and Dunn, 2016). Noise pollution, for instance, can be captured by citizens to map the problem in order to inform local policy makers(Jiang, Kresin, Bregt, Kooistra, Pareschi, van Putten, Volten and Wesseling, 2016). By representing this data visually, it provides insight in a broad range of urban challenges, such as changing demands regarding demographics, transportation, energy consumption, quality of life, crime dynamics, economics of living and so on. Furthermore, through the insight-generation process caused by these visualization, citizens increase their personal and contextual awareness on civic challenges (Lyon, 2001; Elsden, Mellor, Olivier, Wheldon, Kirk and Comber, 2016). Ultimately, access to public data facilitates civic participation processes (DiSalvo, Jenkins and Lodato, 2016). The ability to acquire and process information can thus be considered as a first step towards voicing their opinion and engage in civic debate (Gordon, Baldwin-Philippi and Balestra, 2013). Such citizen participation is often facilitated through online platforms that present public data in an open way (Patel, Sotsky, Gourley and Houghton, 2013; Boehner and DiSalvo, 2016).

Yet citizens struggle to make sense of public data provided in traditional visual representation formats, such as line graphs, bar charts or histograms that require expert knowledge (Balestrini, Diez and Marshall, 2014; Balestrini, Diez, Marshall, Gluhak and Rogers, 2015). If public data is to truly empower citizens, these people should be able to read and deploy visualization formats to gain their own insights and knowledge— not only insights provided by experts (Boy, Detienne and Fekete, 2015). A true understanding of public data is critical when civic participations are expected (Dantec and DiSalvo, 2013), as preparation to participate in public debate (Koeman, Kalnikait and Rogers, 2015), to establish a community (Taylor, Lindley, Regan, Sweeney, Vlachokyriakos, Grainger and Lingel, 2015) or to verify community differences (Korn and Voida, 2015).

The research and practice of information visualization (infovis) mainly focuses however on how the visual representation of data sets can improve the efficiency of analysis by expert users. In contrast, recent research endeavors in human-computer interaction (HCI) have begun to show how a rich variety of visualization approaches can target both non-experts as experts with data (e.g. (Willett, Jansen and Dragicevic, 2017)). Here, the human is placed at the centre of the interaction flows with data (Crabtree and Mortier, 2015; Houben, Golsteijn, Gallacher, Johnson, Bakker, Marquardt, Capra and Rogers, 2016). Situating visualization in public environments where humans move around to live, work, visit, form an opportunistic approach to reach a wide audience of non-experts with public data that is gathered in the actual (physical) context (Vande Moere and Hill, 2012; Taylor, Lindley, Regan, Sweeney, Vlachokyriakos, Grainger and Lingel, 2015). Local data that is also immediately relevant for the context, such as serving local issues or concerns (Claes and Vande Moere, 2013). Featuring such 'public visualization' with input technology for the submission of opinions, votes or sentiments encourages citizens to engage with data (Valkanova, Walter, Vande Moere and Müller, 2014; Koeman, Kalnikait and Rogers, 2015). Yet, the sense-making process of data is not only facilitated by technology, but rather developed through human appropriation and application (Elsden, Mellor, Olivier, Wheldon, Kirk and Comber, 2016). In other words, the context of the visual representation – who sees it, on what terms and with what intentions – becomes as important as the visual and interactive design (Elsden, Mellor, Olivier, Wheldon, Kirk and Comber, 2016). For visual representations that are situated in public space, such as public visualizations, the data refer to the surrounding physical environment (Willett, Jansen and Dragicevic, 2017), which adds complexity to the context as viewers may interpret the perceived owner of the immediate environment as data author (Claes and Vande Moere, 2017).

Situating visual representations in the physical environment thus offers design opportunities to steer interpretation, for instance by making a connection between data and the actual environment (Vande Moere and Offenhuber, 2009; Vande Moere and Hill, 2012). Most existing examples of visualizations are embedded in other media formats, such as newspapers or online channels, which establish a context for decoding the representation by integration in news articles with or without the support of additional (moving) images. Yet for a viewer in a physical environment, such a semantic context is absent (Offenhuber and Seitinger, 2014). However, the public environment offers other contextual clues that help the sense-making process of visualization. For instance, a street sign refers to a specific location. When attaching a visualization to this street sign, it also implies to be representing that location (Claes and Vande Moere, 2013). Besides location, also tacit aspects of the context provide a form of information (Dourish, 2004). The street sign also refers to the identity of that specific location. The street might be known by passers-by to be dangerous for leaving your car unattended, which might influence the interpretation process caused by the visualization. This thesis departs from the assumption that the context contributes to the engagement, the sense-making and insight generation process of citizens that is facilitated through public visualization, i.e. the visual representation of data in the public environment.

## 1.1. Research approach

The work in this thesis is guided by the following overarching research question:

**How can the design of public visualization encourage citizens to generate insights in casual contexts?**

This research is situated in the field of human-computer-interaction (HCI) that studies the design and application of digital interfaces. In particular, interaction design is one of the design disciplines in which designers deal with *wicked* problems, i.e. a formulation that changes throughout the design process (Rittel and Webber, 1973) through a learning process of *reflection-in-action* (Schon, 1984; Schön, 1987). As a result, the design process concerns an iterative approach of thinking, designing, developing, testing and repeating that cycle. These design choices are therefore not strictly rational, yet rely on the *design judgment* of the designer (Nelson and Stolterman, 2003), guided by prior experiences through an *abductive* thinking process (Kolko, 2010).

The main research question is studied through five case studies in which we iteratively designed and evaluated five public visualization demonstrators. These demonstrators provide a space between the generative and the evaluative phases of a design project, thereby providing the opportunity to test the physical representation of an idea in reality without the practical constraints of designing for a finished product (Sanders and Stappers, 2014). Furthermore, research prototypes are used to produce ideas and concepts for public visualization, as to assess the effect or the effectiveness of the public visualization.

Here, the involvement of typical design activities in the research process is the means to produce new knowledge (Fallman, 2007; Zimmerman, Forlizzi and Evenson, 2007). In particular, our research aims to define *bridging concepts* that translate abstract theory to design practice (Dalsgaard and Dindler, 2014), which is relevant to connect knowledge to fast evolving interaction technologies. These concepts are shared as design considerations, guidelines and models, but also in the form of debates that the design demonstrators raise (Koskinen, Zimmerman, Binder, Redstrom and Wensveen, 2011).

As the public context is inherently part of our design, we cannot simply study it in lab conditions (Koskinen, Zimmerman, Binder, Redstrom and Wensveen, 2011). Specifically, to remain ecological valid conditions, our prototypes were implemented and deployed in-the-wild, i.e. the real urban environment (Rogers, Connelly, Tedesco, Hazlewood, Kurtz, Hall, Hursey and Toscos, 2007). Our prototypes invited all spontaneous passers-by to participate, without any operational criteria (Binder, Brandt, Ehn and Halse, 2015). Overall, the development of each of the case studies involved several research and design activities, such as literature review, contextual enquiry, ethnographic studies, co- design workshops, and prototyping. In all case studies, a mixed method approach is applied. For instance, for the evaluation of engagement, methods from the academic field of HCI are borrowed (see Figure 1.2). For the evaluation of the insight-generating capacities of public visualization, we draw on methods from the academic field of infovis. We discuss how decisions were made throughout the design process and the rationale behind them in the individual chapters.

The analyses of our research results are informed through the categorization of annotations via a *grounded theory* approach (Glaser, Strauss and Strutzel, 1968). Then, analyses further occurred through the discussion of research results with co-authors. The reasoning behind these analyses are presented in the individual chapters.

### 1.1.1. My role

With a background and several years of experience in media arts before starting this PhD, I rely on my design judgment to base design choices made in the demonstrators (Nelson and Stolterman, 2003), from the very start of selecting an issue to the actual design and deployment process. It allowed me as a researcher to be positioned in the middle of the design process and study the design process from within. However, during the process, I was constantly aware the dual position of designer and researcher is not evident. As a designer, I aim for my design to be liked. In the evaluation of the design, I therefore paid attention to the exact formulation of the questions to prevent researcher bias.

#### 1.1.1.1. A flexible, exploratory approach

Designing a public visualization that corresponded to a real local issue while also responding to a relevant research question proved challenging to set up. The first study Street Infographics (Chapter 2) was therefore set up without a clear research question beforehand yet the design anticipated on a local issue. Yet the act of placing public visualizations, observing the behaviors it caused and listening to responses of passers-by, informed my design judgment and revealed the potential of public visualization. This experience caused me, for instance, to further study the application of narrative strategies for the design factor of content, as I expected it would encourage engagement of passers-by (Chapter 5). Similarly, in Street Infographics, I noticed the engaging potential of distributing public visualizations (Chapter 6). In contrast, in the second case study (Chapter 3), I defined a clear research question beforehand in which three different set ups could be compared. In this study, participating passers-by appeared to have little time for interviews. Perhaps this was because the public visualization did not respond to a local issue, causing them to be less engaged in the study. To solve this problem, I decided to repeat the study in a more controlled set up, and as such receive more qualitative research data, leading into an additional study on evaluation methods. These examples showcase how my design research process was a constant interplay between the variables of the actual real-world practice and the research context, and was therefore in need of a flexible approach.

#### 1.1.1.2. Researcher bias

As the designer of the public visualization, I felt responsible towards the people who gave the assignment, e.g. city council in *Street Infographics*, the department of mobility of the province of Vlaams Brabant in *Bicycle Barometer* and a citizen group in *Data on Site*, about the success of the demonstrator. I also felt personally committed to the cause of these public visualizations, e.g. promoting cycling and mapping cyclists' opinions in *Bicycle Barometer* and *Narrative Visualization*. I was aware this personal relation with the public visualization could undermine my interpretation of the research data. Therefore, I outsourced the task to colleagues to prevent researcher bias. My involvement in the design process might also be noticeable for the study participants, which we extensively addressed in Chapter 4 (i.e. the role of researcher involvement and its effect on the social reliability of the answers of participants).

#### 1.1.1.3. Designer bias

As a designer, I also found it important the public visualization was attractive to look at. I gave attention to the content in relation to color schemes, typography and materiality of the demonstrators. However, time for design was often limited as the set up of the research approach received priority. In several of my case studies, I did not present the best possible design to my opinion, which was something I struggled with from a designer perspective. However, from a researcher point of view, I believe exactly the unfinished dimensions of the design caused me to be curious and open for comments on the design in order to identify the space for improvement in future design work. This way of approaching the research question helped to think further than the actual design at hand, and reflect on the concept of public visualization.

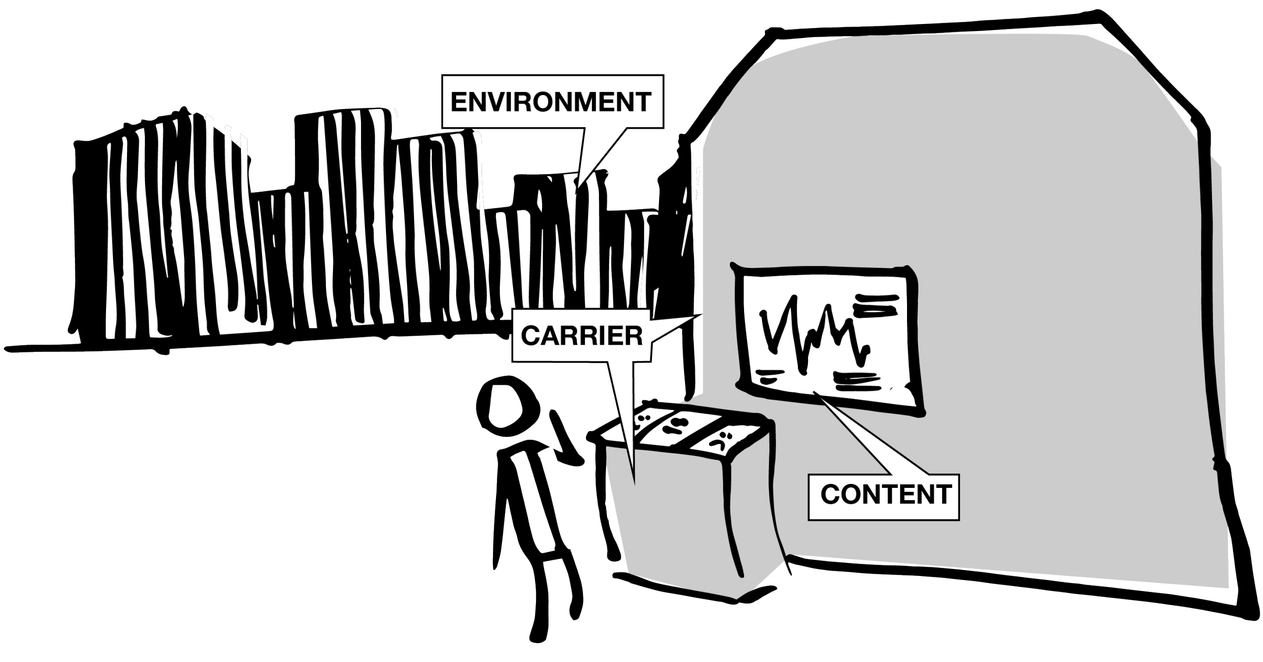


Figure 1.1 The context in which a public visualization resides divided into three design factors: from content (e.g. visualization, data, topic as title) to carrier (e.g. façade, display technology, interaction technology) to environment (e.g. tacit aspects of neighborhood).

### 1.1.2. Casual Contexts

We deploy the term *casual* to highlight the difference with design for task-oriented contexts such as work environments that are typically studied in information visualization (Pousman, Stasko and Mateas, 2007). The term *casual* also emphasizes a difference in the target audience; from *hardcore* or expert to more casual users (Juul, 2010). We consider the public environment as a casual context in this thesis as it allows for a broad range of users to engage with public visualization without a predefined task.

Context thus encompasses more than the physical environment (Dourish, 2004), it also includes the content and the social actions of people surrounding the public displays (Schroeter, Foth and Satchell, 2012). In this thesis and as shown in Figure 1.1, we categorize the design factors of context according to:

**1) Content** consists of the choice of data sources and topic (e.g. a local issue), the visual representation type, labels, titles and other annotations that clarify the subject matter.

**2) Carrier** involves the physical artifact that supports the content and interaction with the content;

**3) Environment** includes the physical (i.e. materiality) and social dimensions (i.e. citizens and their activities) in time,

as discussed from more integrated, media architectural perspective (Vande Moere and Wouters, 2012).

Based on these design factors, we identify three more specific research questions in relation to the state of the art, i.e. content (RQ1), carrier (RQ2) and environment (RQ3).

#### 1.1.2.1. Content

Public visualization deploys data sets that are:

i) contributed through invisible civic infrastructures without the citizen being aware of, e.g. mobile phone traffic (Geneve, 2012), and

ii) volunteered through public polling devices, e.g. submitting sentiments on particular urban challenges (Behrens, Valkanova, gen. Schieck and Brumby, 2014).

Both types are already an integral yet invisible part of public space (Offenhuber and Ratti, 2014). As shown in Table 1.1, most commercial deployments of public visualization present contributed data, such as mobile phone traffic, sensor networks and geographic locations through GPS (e.g. (Geneve, 2012; Helsinki, 2013). Academic examples of public visualization are focused to study the integration of volunteered data (see Table 1.1 such as via public polling (e.g. (Koeman, Kalnikait and Rogers, 2015) or sending messages (Offenhuber and Seitinger, 2014) (see Table 1.1). Studies that focus on the representation of contributed data, however, seem to be missing.

More than ten years ago, the visual design of these representations was mainly based on minimalism (Tufte, 2006), in order to focus attention to the actual chart or graph and not the embellishment surrounding it. Yet at that time, studies in infovis mainly targeted expert users, in order to augment task efficiency in analytic tasks. These functional motivations are now becoming questioned, as a broad audience is increasingly being targeted with data, and more qualitative goals like insight-generation, memorability and discussion are intended (Hullman, Adar and Shah, 2011). It has been shown that visual style (Vande Moere, Tomitsch, Wimmer, Christoph and Grechenig, 2012) and type (Cawthon and Vande Moere, 2007) of a visualization influences the sense-making process in so far that its embellishment can actually significantly influence its first impression (Harrison, Reinecke and Chang, 2015), and lead to insights that are more memorable (Bateman, Mandryk, Gutwin, Genest, McDine and Brooks, 2010).

Consequently, infovis research has shifted its focus to the concerns and expectations of non-expert users, such as why and when people use casual types of infovis (Sprague and Tory, 2012). Engaging people with visualization is essential for the generation of insights. Recent studies have explored narrative visualization strategies as a promising approach to engage a non-expert audience (Boy, Detienne and Fekete, 2015). Because narrative visualization has the ability to partly shift authorship to the viewer (i.e. guiding the viewer to interpret data), it encourages viewers to gradually immerse themselves in the sense-making process and reflect upon the themes that are embodied by the data (Segel and Heer, 2010). Yet the application of narrative strategies to augment engagement with visualization have mainly been studied in controlled settings, e.g. (Boy, Detienne and Fekete, 2015; Zhao, Marr and Elmqvist, 2015). We study the narrative approach for the design of public visualization in non-controlled settings (i.e. the public space) in Chapter 5 of this thesis, guided by the following research question:

> *RQ1*
> *How can a narrative approach of public visualization affect engagement and insight generation?*

#### 1.1.2.2. Carrier

Today's public visualizations are supported via different output media, ranging from public displays (e.g. projections (Valkanova, Jorda, Tomitsch and Vande Moere, 2013) or LED displays (Behrens, Valkanova, gen. Schieck and Brumby, 2014)), to *physicalizations,* i.e. visual representations with physical dimensions (Taylor, Lindley, Regan, Sweeney, Vlachokyriakos, Grainger and Lingel, 2015; Willett, Jansen and Dragicevic, 2017), and static carriers present in the public environment (e.g. chalk on pavements (Koeman, Kalnikait and Rogers, 2015) or signs that are attached to facades (Vande Moere, Tomitsch, Hoinkis, Trefz, Johansen and Jones, 2011)). Table 1.1 presents an overview of key examples of public visualizations in an academic, artistic and commercial context.

As shown in Table 1.1, interaction with public visualization mostly occurs when citizens voluntarily submit data, collected via the visualization interface, e.g. via touch interactions (Helsinki, 2013; Valkanova, Jorda, Tomitsch and Vande Moere, 2013), mobile phone messages (Offenhuber and Seitinger, 2014), or tweets (Colangelo, 2014).

Volunteered input, such as public polling is a design strategy to actively engage citizens with public visualization, enabling them to reflect on the presented local issue (Koeman, Kalnikait and Rogers, 2015). Submitting data via public displays encourages community engagement (Hespanhol, Tomitsch, McArthur, Fredericks, Schroeter and Foth, 2015), activates newcomers in public life (Schroeter, 2012) or acts as a trigger for public debate (Koeman, Kalnikait and Rogers, 2015).

Interaction to inspect the visualization, such as exploring, filtering, or selecting information, is a design strategy to encourage insight-generation on the data in specific (Card, Mackinlay and Shneiderman, 1999). The interactive features of public displays range from gesture-based interaction (Müller, Walter, Bailly, Nischt and Alt, 2012), over touch interaction (Ojala, Kukka, Lindén, Heikkinen, Jurmu, Hosio and Kruger, 2010) to external device interaction (Ardito, Buono, Costabile and Desolda, 2015). Here, one of the main design challenges is framed as 'interaction blindness' (Ojala, Kostakos, Kukka, Heikkinen, Linden, Jurmu, Hosio, Kruger and Zanni, 2012), referring to the inability to notice the interactive possibilities of a public display in a busy environment. Physical or tangible types of interaction are believed to be able to overcome interaction blindness, as it triggers curiosity (Houben and Weichel, 2013) while facilitating the exploration of specific information (Dourish, 2004). This argument is consistent with recent calls to integrate interactive features of embedded representations, including public visualization, in (elements of) the visualization carrier to support the insight-generation process (Willett, Jansen and Dragicevic, 2017). We studied the interactive possibilities for interaction with visualization output through supporting the carrier with interactive, physical plates in chapter 3:

> *RQ2*
> *How does the use of physical interaction elements impact engagement and insight generation with public visualization?*

### 1.1.2.3. Environment

Physical dimensions are an integral part of the design of situated technology for a public or urban context (Fischer and Hornecker, 2012). Public displays are most often positioned at busy squares, train stations and other frequented locations (Müller, Alt, Michelis and Schmidt, 2010). When one location is not sufficient to reach the target audience, for instance because of the lack of one key location where all the community members meet, public displays can be distributed over the environment (Taylor, Marshall, Blum-Ross, Mills, Rogers, Egglestone, Frohlich, Wright and Olivier, 2012; Koeman, Kalnikait and Rogers, 2015; Johnson, Vines, Taylor, Jenkins and Marshall, 2016). The public visualizations are thus situated in differing environments, thereby changing the surrounding physical referents of the visualization, which might influence the generated insights (Willett, Jansen and Dragicevic, 2017). We question how the surrounding environment affects the interpretation, and insight generation process in general, which is studied in chapter 4 and 6:

> *RQ3*
>
> *How do specific environmental conditions of public visualization affect engagement and insight generation?*

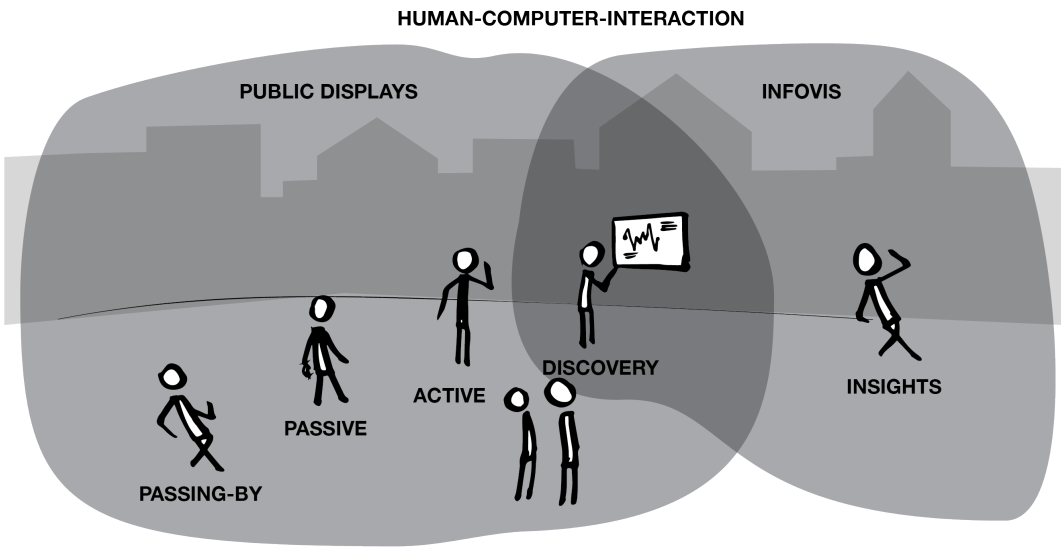


Figure 1.2 Overview of the different engagement stages of public displays; from passing-by, passive to active engagement to discovery, which results in the generation of insights. A viewer discovers information and walks away with insights, which is typically studied in information visualization (infovis). The figure also gives an overview of how these two subfields are situated in the academic field of human-computer-interaction.

#### 1.1.2.4. Insight-generation

In recent years, the infovis domain has developed an interest to reach a lay public, which resulted in attention to novel evaluation methods, such as quantifying interactions as an indication for the depth of engagement (Boy, Detienne and Fekete, 2015), a reporting scale to code the depth of the insights (Saraiya, North and Duca, 2005) and an interviewing approach to evaluate memorability (Borkin, Vo, Bylinskii, Isola, Sunkavalli, Oliva and Pfister, 2013). The main purpose of infovis is to generate insight (Card, Mackinlay and Shneiderman, 1999; North, 2006), which refers to deploying visual representations to discover previously unknown knowledge in data or verify existing hypotheses on data (Munzner, 2014).

An insight is therefore considered as a unit of discovery, an individual observation about the data by the citizen (Saraiya, North and Duca, 2005). Such discovered insight can be one simple fact, e.g. 'the city is increasingly investing means in waste management', or relations between two or more data sets, e.g. 'the city is increasingly investing means in waste management as more waste has been reported'. Insights are thus the product of the cognitive process behind the interpreting of visualization, which can be categorized according to three levels of depth: elementary, intermediate, and comprehensive (Bertin, 1973). The *elementary level* concerns the simple extraction of information from the data. The *intermediate level* concerns the detection of trends and relationships. The *comprehensive level* concerns the comparison of whole structures, and inferences based on both data and background knowledge. This model connects to a similar models for interpreting visualization in mathematics (Curcio, 1987) and bio-informatics (Saraiya, North and Duca, 2005). In this thesis, we code insights according to a categorization defined in the subfield of casual visualization (Pousman, Stasko and Mateas, 2007). Casual types of visualization aims for three *insight types*, such as: 1) *awareness* insights, which deal with maintaining awareness of a particular data stream in order to keep people on top of trending issues; 2) *reflective* insights, which are insights about oneself, the world, and one's place in it; and 3) *social* insights, or insights about social life, the sense of understanding of a social group and one's place in it (Pousman, Stasko and Mateas, 2007).

Yet, before citizens can be involved in the process of insight-generation, they need a motivation to engage with the visualization. In casual contexts, the citizen will first observe the presence of the visualization, without recognizing the data (Sprague and Tory, 2012). Then, she will recognize the content or the carrying artifact and identify a goal to engage with the artifact or not (Pinker, 1990; Trickett and Trafton, 2006), thereby allowing two cognitive processes to occur (Shah, 1997):

1. a top-down process where the viewer's prior knowledge of semantic context influences data interpretation, and
2. a bottom-up process where the viewer shifts from perceptual processes to interpretation.

These two phases take place in alternating cycles, and suggest that both visual encoding and content knowledge influence the interpretation of visualization (Freedman and Shah, 2002).

Goals can be intrinsic, such as wanting to learn or understand information, or being entertained (Munzner, 2014); or extrinsic, such as peer pressure. Although few engagement models or even empirical studies on engagement infovis exist (Saket, Endert and Stasko, 2016; Hung and

Parsons, 2017), engagement is commonly measured and evaluated using metrics as 'the count of user interactions', and 'time spent on view' (Boy, Detienne and Fekete, 2015; Mahyar, Kim and Kwon, 2015). Yet engagement is a complex construct of subjective experiences (O'Brien and Toms, 2008). These metrics are limited to evaluate deeper levels of engagement, including the process of approaching visualization (Mahyar, Kim and Kwon, 2015). Yet novel methods to evaluate such initial engagement stages are urgent when targeting a non-expert audience with visualization (Boy, Detienne and Fekete, 2015). In this thesis, initial engagement is defined as the stages of approaching visualization (i.e. without interaction) and exploring visualization to answer *initial* questions (i.e. through interaction), after which a viewer might generate new questions to further explore visualization. In casual visualization, the Promoter-Inhibitor Motivation model (PIMM) (Sprague and Tory, 2012) recognizes and facilitates the study of viewer's motivations to explore visualization and interact over a longer period of time. PIMM allows us the study the transition from recognizing interesting data to deepen into interaction.

In the field of public displays, engagement is defined as the experience of being involved, as evidenced by behaviors such as looking, studying, exploring content, submitting content, and discussing with other citizens, which can be evaluated through (video or researcher) observation. Frameworks exist that focus on the study of dynamic aspects (Dalsgaard, Dindler and Halskov, 2011), spatial aspects (Fischer and Hornecker, 2012) and ambient aspects (Vogel and Balakrishnan, 2004) of engagement with public displays. However, in this thesis, we build upon the Passive-Active-Discovery (PACD) model (Memarovic, Langheinrich, Alt, Elhart, Hosio and Rubegni, 2012) as it approaches engagement in a nested way instead of a linear fashion. In particular, engagement ranges from

- passive (e.g. glancing at the public visualization, watching others interact),
    - over active (e.g. stopping to read or inspect the public visualization for a brief period) (Carr, 1992),
        - to discovery (e.g. inspecting the actual visual representation) (Memarovic, Langheinrich, Alt, Elhart, Hosio and Rubegni, 2012)

(see also Figure 1.2)

We will study how we can evaluate engagement and the insight generating capacities of public visualization in Chapters 3, 4, 5 and 6, guided by following question:

*RQ4*

*How can insight generation caused by public visualization be evaluated in casual contexts?*

Table 1.1 Existing examples of public visualization in academic (including the case studies of this thesis), artistic and commercial contexts.

| **References** | **Content** | | **Carrier** | | **Environment** |
|---|---|---|---|---|---|
| | Data | Visualization | Physical | Interaction | |
| **Academic** | | | | | |
| Reveal it (Valkanova, Jorda, Tomitsch and Vande Moere, 2013) | Energy consumption | Sunburst | Projection in public art centre | Volunteered input | Public art centre |
| Neighborhood Scoreboards (Vande Moere, Tomitsch, Hoinkis, Trefz, Johansen and Jones, 2011) | Energy consumption | Line chart, Ranking, Infographic | Chalkboard on facade | Contributed input | Distributed over street |
| My position (Valkanova, Walter, Vande Moere and Müller, 2014) | Polling results | Bar graph | Projection on supermarket | Volunteered input | Supermarket |
| SCSC(Behrens, Valkanova, gen. Schieck and Brumby, 2014) | Polling results | Sunburst | LED Media facade | Volunteered input | Street in Media arts festival |
| Visualising Mill Road (Koeman, Kalnikait and Rogers, 2015) | Polling results | Matrix | Chalk on pavement | Volunteered input | Distributed over neighborhood |
| Tenison Road (Taylor, Lindley, Regan, Sweeney, Vlachokyriakos, Grainger and Lingel, 2015) | Polling results | Pie chart | Physicalization behind office window | Volunteered input | Street |
| Tidy Street (Bird and Rogers, 2010) | Energy consumption | Line graph | Chalk on street | Volunteered input | Street |
| Vote as you Go (Hespanhol, Tomitsch, McArthur, Fredericks, Schroeter and Foth, 2015) | Polling results | Bar graph | Public LED display | Volunteered input | Public square |
| Dotvot.es (Offenhuber and Seitinger, 2014) | Polling results | Bar graph | Lights behind windows | Volunteered input | University campus |
| **References** | **Content** | | **Carrier** | | **Environment** |

| | | | | | |
|---|---|---|---|---|---|
| **Case studies** | | | | | |
| Street Infographics (Chapter 2) | Demographics | Matrix | Extension to street sign | None | Distributed over neighborhood |
| Sight on local data (Chapter 3) | Demographics, Energy, Crime, … | Line graphs | Touch screen in physical telescope | Output | Shopping street |
| Bicycle Barometer (Chapter 4) | Bicycle counts, Polling results | Line graph, Bar chart | LED display in construction | Contributed, volunteered input and Output | Bicycle lane |
| Narrative visualization (Chapter 5) | Bicycle counts | Line graph | Public touch screen | Output | Public library |
| Data on Site (Chapter 6) | Air pollution | Line graph, Bar chart Matrix | e-Ink displays on facades | Contributed &volunteered input | Distributed over neighborhood |
| **Artistic** | | | | | |
| Nuage Vert (Hehe, 2008) | Air pollution | Metaphoric | Chimney smoke | None | Industrial site |
| Tree (Heijdens, 2004) | Pedestrian flow | Network | Projection | Input/Output | Street |
| Fuehlometer (Bismarck, Wilhelmer and Maus, 2001) | Sentiment | Metaphoric | Neon sign | Contributed input | Ring road |
| Data data data (Stanza, 2011) | Urban flows | Network | Projection | Contributed input | Street |
| Dot by Dot (Streamers, 2014) | Polling results | Bar chart | Sculpture | Input | Public square |
| Reactive Sparks (Art+Com, 2008) | Traffic flow | Ambient | LED display | Contributed input | Ring road |
| Binary (Lab[au], 2008) | Urban flows | Bar chart | LED display | Contributed input | Bridge, train station |
| Bicycle usage (Birt, 2012) | Bicycle counts | Infographics | Projection | Contributed input | Art |
| **References** | **Content** | | **Carrier** | | **Environment** |
| Bloc jam (yours, 2010) | Mobile phones | Bar chart | Window lights | Contributed input | Art |

| | | | | | |
|---|---|---|---|---|---|
| Watermarks project (Bodle, 2009) | Water levels | Metaphoric | Projection | None | Art |
| In the air tonight (Colangelo, 2014) | Sentimen t | Ambient | Window lights | Volunteered input | University campus |
| Geometric Death Frequency (Diaz, 2010) | Pedestria n flow | Bubble chart | Physicaliza tion | Volunteered input | Public art |
| Street graphs (Unknown, 2015) | Housing prices | Bar charts | Sculpture | None | Street |
| **Commercial** | | | | | |
| Urban Flow (Helsinki, 2013) | Urban flows | Map | Public touch screen | Output | Shopping street |
| Energy consumption (Sixteen-nine, 2014) | Energy consump tion | Bar charts | Display | None | Street |
| Bicycle counter (Eco-counter, 2017) | Bicycle counts | Bar chart | Display | Contributed input | Bicycle lanes |
| Ville Vivante (Geneve, 2012) | Mobile phone traces | Line graph<br>Bar chart<br>Bubble chart | Static sign | None | Shopping street |
| Come to your Census (Spinifexgroup, 2012) | Demogra phics | Bubble chart<br>Pie chart<br>Infographic | Projection | Output | Media arts festival |

## 1.2. Thesis overview

Table 1.2 presents an overview of the following 6 chapters of this thesis and their contributions. Upon the start of this research, only few examples of public visualization existed. Chapter 2 (*Street Infographics*) was therefore set up as an exploratory study to identify general design characteristics of public visualization, thereby focusing on RQ1, RQ2 and RQ3. The study in chapter 3 (*Sight on Local Data*) investigates RQ2, chapter 4 (*Bicycle Barometer*) focuses on RQ3 and RQ4, chapter 5 (*Narrative Visualization*) concentrates on RQ1, and chapter 6 (Data on Site) explores RQ1, RQ2 and RQ3. Each chapter presents the deployment of a public visualization demonstrator (see Figure 1.3), and is concluded with a number of design considerations for public visualization (see Table 1.2). The chapters are presented in a chronological order as it demonstrates how the application of the insight reporting methodology iteratively evolved over the case studies (and presented in the final chapters as ERI model). Also, the chronological presentation of the studies represents the general evolution of public visualization as a research topic. For instance, as also presented in the personal note in Chapter 2, the publication on *Street Infographics* discusses *urban* visualization instead of *public* visualization, as the term was relatively unknown at the time. Yet throughout the years, the term public visualization was adopted by the HCI community, which is also reflected in our publications. Finally, in chapter 7, we combine our insights into design guidelines for public visualization, and present a discussion on the five public visualization demonstrators that were developed in the course of this research.

## 1.3. Research ethics

Public visualization aims to make public data, including its capturing process, transparent. To be consistent with this goal, also the capturing process of the research data in our case studies (e.g. through observations) should be made explicit. All the demonstrators included a poster or note to inform onlookers about the aim of the study, the involved university, department, researcher and her contact details, and the possibility they are being observed by the researcher and can be approached for interview purposes.

Signed informed consents were obtained of participants in the co-design workshops (Chapter 4 and 6), as well as for interviews that took longer than 10 minutes (Chapter 2, 3 and 6). The consents included the aim of the research, how the data will be handled and stored, and stated they could drop out of the study at any time. Onlookers that were approached for a short interview on the street were informed about the research goal and interview intentions before the interview. Participants were allowed to refuse the interview or to opt out of the observations.

In Sight on Local Data, we reported our set up to film the public environment to the Privacy commission (key 1407762991063). In Data on Site, we obtained permission of the Ethical commission of KU Leuven (key G-2017 060 847).

Table 1.2 Overview of the chapters and their contributions

| Chapter | Main contributions |
|---|---|
| 3. Street Infographics | Six design principles for public visualization;<br>Understanding of the design potential of public visualization;<br>Identification of the role of spatial distribution in public visualization. |
| 4. Sight on Local Data | Identification of the role of physical design characteristics;<br>Four design recommendations for public visualizations. |
| | Novel evaluation method for controlling in-the-wild studies. |
| 5. Bicycle Barometer | Identification of how targeting a specific civic audience encourages engagement with public visualization;<br>Eight design recommendations for cyclist-specific interaction with a public display;<br>An interactive public visualization for cyclists. |
| | Identification of how material dimensions affect engagement with public visualization;<br>The replication of an in-the-wild study. |
| 6. Narrative Visualization | Identification of the role of:<br>1) Narrative design strategies;<br>2) The surrounding environment;<br>on insight-generation through public visualization. |
| 7. Data on Site | A public visualization toolkit;<br>Identification of different contextual influences;<br>Seven design recommendations for designing distributed public visualization. |
| 8. Discussion | Evaluation model for public visualization;<br>Design guidelines for public visualization;<br>Five demonstrators of public visualization. |


Figure 1.3 The five public visualization demonstrators presented in this thesis range from one of the four augmented street signs in Chapter 2, Street Infographics (top left), over a telescope installation with physical interaction elements in Chapter 3, Sight on Local Data (top right), a cyclist-specific interactive display in Chapter 4, Bicycle Barometer (middle left), a Narrative Public Visualization on a touch screen in Chapter 5 (middle right) and one of the eight public visualization toolkits of Data on Site in Chapter 6 (below).

## 1.4. Publications

The main body of this thesis (Chapter 2 to 5) consists of research that was published in academic peer-reviewed conferences over the course of the doctoral research[1]. The publication that is referenced in Chapter 6 has been submitted to a conference on human factors in design and is currently under peer review. This chapter will be resubmit if not accepted. Each paper discusses research questions, related work and analysis for the particular case.

Chapter 2

Claes S., Vande Moere A. (2013). Street Infographics: Raising Awareness of Local Issues through a Situated Urban Visualization. International Symposium on Pervasive Displays. PerDis'13. Mountain View, CA, USA, 4-5 July 2013(pp. 133-138) ACM.

Chapter 3

Claes S., Vande Moere A. (2015). The Role of Tangible Interaction in Exploring Information on Public Visualization Displays. International Symposium on Pervasive Displays. PerDis'15. Saarbrucken, Germany, 10-12 June 2015 (pp. 201-207) ACM.

Claes S., Wouters N., Slegers K., Vande Moere A. (2015). Controlling In-The-Wild Evaluation Studies for Public Displays. Conference on Human Factors in Computing Systems. CHI'15. Seoul, South Korea, 18-23 April 2015 (pp. 81-84) ACM.

Acceptance rate: 23%

Chapter 4

Claes S., Slegers K., Vande Moere A. (2016). The Bicycle Barometer: Design and Evaluation of a Cyclist-Specific Interaction for a Public Display. International Conference on Human Factors in Computing Systems. CHI'16. San Jose, US, May 7-12 (pp. 5824-5835) ACM.

Acceptance rate: 23%

Claes S., Vande Moere A. (2017). Replicating an In-The-Wild Study One Year Later: Comparing Prototypes with Different Material Dimensions. International Conference on Designing Interactive Systems. DIS'17. Edinburgh, UK, 10-14 June (pp. 1321-1325) 2017 ACM.

Acceptance rate: 22%

[1] A complete overview of publications, including those not included in this thesis, can be retrieved from https://lirias.kuleuven.be/cv?u=U0049795

Chapter 5

Claes S., Vande Moere A. (2017). The Impact of a Narrative Design Strategy for Information Visualization on a Public Display. International Conference on Designing Interactive Systems. DIS'17. Edinburgh, UK, 10-14 June 2017 (pp. 833-838) ACM. Acceptance rate: 22%

Chapter 6

Claes S., Coenen J., Vande Moere A., Data On Site

Submitted to 2018 International Conference on Human Factors in Computing Systems, CHI’18.

Appendix

Claes S., Vande Moere A. (2017). What Public Visualization Can Learn from Street Art. Leonardo - Art, Science and Technology, 50 (1), 90-91.

## 2. Case study I: Street Infographics

This study is published as

Claes S., Vande Moere A. (2013). Street Infographics: Raising Awareness of Local Issues through a Situated Urban Visualization. International Symposium on Pervasive Displays. PerDis'13. Mountain View, CA, USA, 4-5 July 2013(pp. 133-138) ACM.

DOI: 10.1145/2491568.2491597

Presented at PerDis'13 conference on June 5, 2013 in Mountain View, USA.

## My role

*The study presented in this chapter aimed to be exploratory, and was executed in the first three months of the PhD trajectory.*

*On suggestion of Andrew Vande Moere, I contacted the data department of the city of Leuven, who presented me several locally relevant issues that concern data of particular neighborhoods.  After close inspection of available data, I contacted the responsible community manager of one of the neighborhoods. A field visit to the neighborhood inspired me to do deploy the identity bearing capacity of street signs in relation to data.  I distributed the signs in the streets on a Friday night in the beginning of January 2013 with the help of my husband, observed the signs for the following week and did interviews with passers-by (as illustrated on Figure 2.1).*

*In this chapter, we use the term 'urban visualization', as we were exploring the concept of public visualization at the time. The resulting publication was authored primarily by myself, with support from Andrew Vande Moere.*


Figure 2.1 An interview with a passer-by in the Ravenstraat in Leuven.

Figure 2.2 Augmented street sign of 'Bogaarden' street in the city of Leuven, Belgium.

**Abstract**

*This chapter presents the evaluation study of Street Infographics, an urban intervention that visually represent data that is contextually related to local issues, and is visualized through situated displays that are placed within the social and public context of an urban environment. Based on the design characteristics of urban visualization, we defined six specific design principles and applied these in the deployment of a low-fidelity prototype during an in-the-wild study. Designed to augment an existing street sign with socially- and locally-relevant information, the resulting urban visualization encourages people to gain local knowledge, reflect on their perception and even foster social interaction. We describe the design of Street Infographics and its effect on local residents, as measured before and after our intervention. Our case study should be considered one of the first steps towards a better understanding of the true potential of the use of data visualization in a public context, such as for engaging citizens in acting towards a more qualitative and sustainable neighborhood.*

## 2.1. Introduction

Humans are becoming an urban species, living in a large number of vast urban agglomerations. We face a broad range of challenges of which the changing demands of demographics, transportation, energy consumption, quality of life, crime dynamics, economics of living, culture and art are just a few. It is therefore critical and urgent that the urban population acquires a truer understanding of the principles and tendencies behind the growing global city (Redhead and Brereton, 2006), in order to encourage them in acting towards a more qualitative and sustainable neighborhood. In short, 'smart' cities thus require 'smart' citizens, at least when more considerate civic responses and participations are expected. However, engaging stakeholders presupposes a complex way of communication, involving both discursive and pictorial information. Such information tends now to be delivered via maps, infographic illustrations or other sophisticated means of narrative visualization (Segel and Heer, 2010) that is distributed via various media channels, ranging from books and brochures, to dedicated websites and social media.

However, no two cities in the world, or even two neighborhoods within the same city, are identical in the issues they face today. Identifying and sharing such hyper-local urban issues typically requires a higher resolution of data, as well as a more localized way of communication. One of the most obvious locations for communicating such 'situated' information seems to be the physical environment itself (Vande Moere and Hill, 2012), the actual subject and catalyst of the issues that have been captured in data. The urban environment, in its ability to shape and reproduce the local norms and rules of social interaction, plays a critical role in the construction and reflection of social behavior. Moving through the city has always been a performative practice where the citizen interprets the world for her own purposes and enjoyment (Galloway, 2004). What we therefore propose is that the physical environment has the potential to act as an information-carrying medium in its own right, while bringing a much richer, multimodal and spatial experience than most traditional, screen-based methods.

The display of local, abstract information within the urban environment has already become increasingly ubiquitous, ranging from road signs that indicate the local traffic situation, over real-time timetables at bus stops, to dynamic information boards that advertise local cultural events. Accordingly, we believe that the situated, visual representation of contextually relevant information forms an ideal method to reach an inherently interested audience in an opportunistic way. More specifically, we draw upon the concept of urban visualization, the visual representation of urban data through a display that is also situated within that urban environment (Vande Moere and Hill, 2012).

In this chapter, we investigate the potential of urban visualization as a means to encourage residents of a neighborhood community to reflect, analyze or engage with local issues. We apply the design characteristics of urban visualization in an urban intervention coined Street Infographics and conduct an explorative in-the-wild evaluation study. We conclude with a discussion on the impact of these principles, based on our results.

## 2.2. Related work

Emerging phenomena like urban informatics (Foth, 2008) the quantified self and others demonstrate there is an increasing expectation that the digital world should be more explicitly merged with our physical existence, and vice versa. An urban or public screen, as an electronic window that is conveniently located in our everyday environment, seems to offer an ideal medium to bridge the digital with the physical and the social, e.g. by extending the visibility of civic issues (Schroeter, 2012), by supporting social interactions (Vogel and Balakrishnan, 2004), or by influencing the sense of community (McCarthy, Farnham, Patel, Ahuja, Norman, Hazlewood and Lind, 2009; Memarovic, Langheinrich, Alt, Elhart, Hosio and Rubegni, 2012). However, despite the fact that the social potential of urban screens has been recognized (Struppek, 2006), the majority of urban screens, still serves commercial, artistic or entertainment purposes (Schieck, Briones and Mottram, 2008). Accordingly, the potential of public display to push local issues has still not been fully explored.

Several projects have demonstrated how visualization, located in a public or urban context, has the ability to engage residents in socially relevant topics such as energy consumption, for instance by means of house-attached data dashboards (Vande Moere, Tomitsch, Hoinkis, Trefz, Johansen and Jones, 2011), interactive projections (Valkanova, Jorda, Tomitsch and Vande Moere, 2013), or by exploiting the street itself as a display surface (Bird and Rogers, 2010). Installing representations in the street is not a particularly new idea since it forms a natural and accessible medium for community expression, including manifestations, street or guerilla art, posters and so on, able to reach a wide and rich range of stakeholders in different, opportunistic ways. It has been used as a top-down communication medium to offer citizens a new understanding of their environment, for instance allowing the city of Geneva to present visualizations of various local digital traces by way of a physical exhibition of a number of infographic illustrations (Geneve, 2012)(see Figure 2.3a). On the other hand, several bottom-up initiatives exist, such as "Walk (Your City)" (Tomasulo, 2012) which is a – by guerilla art inspired – project consisting of several DIY signs that were installed to persuade local residents to walk across their city (see Figure 2.3b). Similarly, "Infoviz Graffiti" (Lenvin, 2010) is an open toolbox to create meaningful visualizations in the public environment by way of spray painting (see Figure 2.3c). While these examples show the usefulness of situating visualizations within the physical public domain, they also demonstrate how the representation of data with local and social relevance seems still underexplored (Vande Moere and Hill, 2012).

## 2.3. Street Infographics

We designed an urban intervention coined Street Infographics to evaluate a seemingly obvious way of contextualizing information in the physical realm, here by augmenting four existing street signs with infographic illustrations (see Figure 2.4). For each of the four streets, we implemented a unique infographic illustration that reflected the situation of that specific street, as captured by socio-demographic data that was retrieved from the local council, such as age distribution, profession, nationality, household typology, and crime rates. The intervention was installed in *Mussenwijk* (see Figure 2.4), a small neighborhood in the center of Leuven, a mid-size city in Belgium. This particular neighborhood was chosen for: 1) the relative absence of social cohesion, confidence or control, as indicated by a recent large-scale study by the local police (Meuwissen, 2011); 2) its vicinity to the commercial district and its visibility to occasional passers-by as well as local residents; 3) its relatively high percentage of young residents, i.e. 53.4% are 20-39 years compared to 35.4% city-wide; and 4) the planning of a student housing


Figure 2.3 Existing examples of infographic illustrations in the street: a) a collection of information visualizations of citizen's digital traces, b) guerilla wayfinding, and c) pie char visualization with stencil.

complex at the border of the neighborhood, which has provoked local concerns about the unequal distribution between students and permanent residents.

### 2.3.1. Design

We based the design of Street Infographics on the 12 general design characteristics of urban visualization (Vande Moere and Hill, 2012), which were interpreted into six more specific guidelines in order to focus on the local and social purpose of the intervention.

**Local and Social.** The represented data has a direct relationship to the environment it is presented in, for instance in terms of where the data originates from, or in its perceived relevancy to its audience.

Accordingly, Street Infographics connected to the local civic issues at hand, communicating relevant information on the level and interests of the residents living or frequenting the street. Based on the contextual situation as well as on our own pre-study interviews (see Evaluation2.3.2), we decided to inform the local concerns regarding the perceived student population by comparing the number of students and permanent residents for each street in the neighborhood.

**Aesthetic and Medium.** The physical presence of an urban visualization should be in line with the physical and visual nature of a location, such as in terms of its materiality, color, size, or proportionality.

In Street Infographics, most visual features were integrated with that of a street sign, such as its proportion, font type and background color. This way, the infographic illustration appeared to be part of the urban fabric (see Figure 2.2), while also providing a subtle change in the familiar environment (i.e. the proportionally extension of the street sign) to attract the attention.

**Insightful and Persuasive.** The power of some visualizations lie in their narrative capacities to reveal meaningful 'stories' that are supported by some objective facts, i.e. data (Segel and Heer, 2010). Therefore, an urban visualization can become more than the graphical communication of simple facts or figures. The deliberate act of 'visualization' should aim to empower onlookers to discover meaningful insights, even elicit reflection, change or action. The true value – and therefore the success – of an urban visualization thus probably depends on how it is able to 'inform' its onlookers.

We designed four infographic illustrations in order to facilitate the comparison of the data from different streets against each other. To encourage a more personal and intuitive identification with the demographic data, Street Infographics depicts percentile values as a series of human icons. For instance, there are 88% permanent residents (88 human figures) and 12% students (12 human figures) in Mussenstraat (shown in Figure 2.5). To encourage further or deeper forms of interpretation – i.e. the discovery of more complex correlations and trends that are not apparent if the variables are viewed individually – the graphic also included the relative presence of (Belgian versus non-Belgian) nationalities, which is highlighted by the yellow color. In Mussenstraat, the graph thus revealed how almost half of the foreign population (13% or 13 human figures) exists of international students (5% or 5 human figures).

**Contextual.** An urban visualization should exploit the unique 'meanings' that are inherently present within the physical environment. This can either be accomplished by the use of a situated metaphor, so that a display on a façade of a governmental institution can be perceived as more trustworthy than on a private building, such as displaying governmental statistics on a public institution (Spinifexgroup, 2012), or by the use of affordances, i.e. clues in the environment that indicate possibilities for action, such as conveying the predicted rising local water levels by way of a life-scale projection (Bodle, 2009).

In Street Infographics, we visually connected the visualization to the official street signs, and thereby exploited its location-bearing value to denote what the data meant, i.e. information about the particular street. To ensure people would be inclined to compare the data values of different streets, we planned to install the four infographic illustrations at two separate street crossings: one with high (i.e. close by shopping area, see Figure 2.4 A) and the other with medium pedestrian traffic (see Figure 2.4 B).

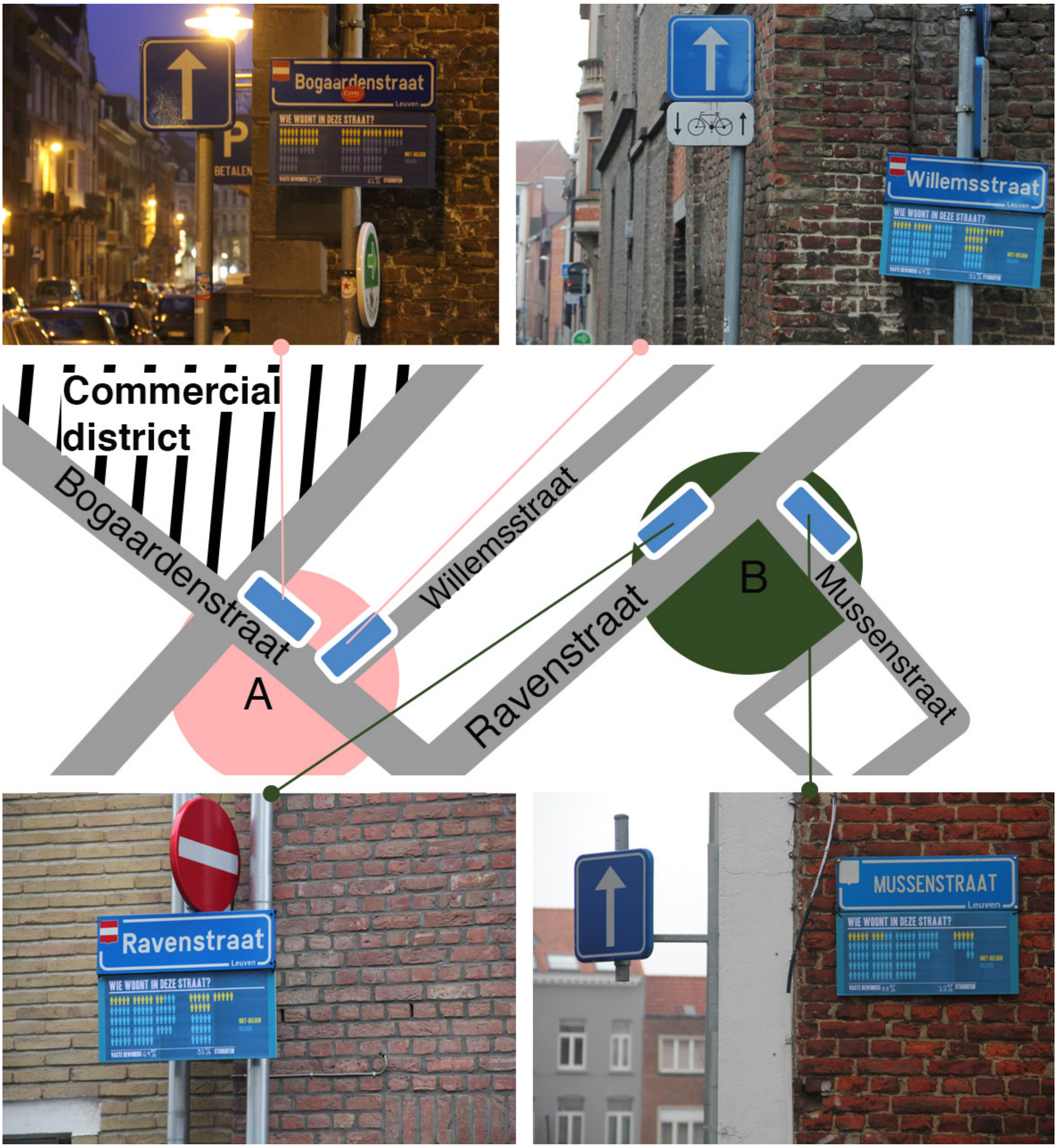


Figure 2.4 Street crossing A with street sign Bogaardenstraat and Willemsstraat and street crossing B with street sign Ravenstraat and Mussenstraat.

**Opportunistic.** Due to its explicit public nature, an urban visualization should be able to reach 'everyone', regardless of technical proficiency or socio-demographic background. In addition, an urban visualization should not impede in civic activities, yet create the opportunity for passers-by to engage with it or not.

In Street Infographics, we deliberately chose to design infographic illustrations, which are a type of *casual information visualization,* in that the data sets are personally meaningful, and designed to be comprehensible for a wider set of audiences (Pousman, Stasko and Mateas, 2007). In terms of the physical environment, we considered balancing the four stages of public interaction (Vogel and Balakrishnan, 2004), facilitating transitions from implicit to explicit, public to personal interaction. We corresponded the font size of the visualization's title "Who lives in our street?" (Figure 2.5) to the font size of the existing street signs in order to be readable form a distance. Also the size of the visualization and the contrasting colors were chosen based on the requirements of immediate accessibility and readability. Accordingly, passers-by should be able to get a sense of the overall information space with a quick glance.

**Trustworthy.** The obvious public character of urban visualization implies that any information shown should be correct and up-to-date. In order to establish trust between creators and viewers, an urban visualization should detail where the underlying data is originating from, which aspects are selected, and how the representations are generated (Vande Moere and Hill, 2012).

In the design of Street Infographics, the actual data source of Street Infographics was stated on the back of the signs, which was at least clearly visible on those signs attached to a pole. The source was deliberately displayed in a less obvious way, in order to trigger discussion about the purpose of the sign. This ambiguity of information impels people to question for themselves the truth of a situation and thus reflect on the displayed issue (Gaver, Beaver and Benford, 2003).

Similarly, such ambiguity can be found in the principles of insightful and opportunistic. Insightfulness is often created through ways of contrast and negation, yet the principle of opportunistic prescribes not to obstruct urban everyday life. The six guidelines are therefore not always obvious to combine. However, we believe it is the tension between these guidelines that open new design opportunities that intrigue and elicit social interaction.

### 2.3.2. Evaluation

**Pilot study.** Before installing Street Infographics, we conducted a small user study with six people in order to ascertain whether the graphical depictions were readily comprehensible. We then improved the general visibility by enlarging the font size and widening the space between the groups of human icons. We also tested the feasibility of the signs during one day in a different city to validate its appeal (e.g. did people notice it?) and the robustness in harsh weather conditions (e.g. rain and wind proof). The resulting infographic illustrations were then printed on plywood panels and attached on the existing metal street signs with zip ties (see Figure 3).


Figure 2.5 Overview of infographic illustration for Mussenstraat: (1) Existing street sign, (2) Title: "Who lives in this street", (3) permanent residents 88%, (4) students 12% and (5) non-Belgian and Belgian nationalities.

**Pre-study interviews.** Before deployment, we conducted semi-structured interviews with 20 residents of the four streets, i.e. five residents per street. We used door knocking to recruit residents (Davies, 2011), based on a given list of available household typologies. We were thus able to interview one single person, one young family, one student, one international inhabitant and one elderly couple per street. In order to measure the perceived social cohesion in the community, we asked for the opinions of residents and invited them to estimate the relative number of students and immigrants living in the street on a scale from 0 to 10. We deliberately never mentioned our planned Street Graphics intervention.

**Observations.** The four street visualization signs were continuously installed during one week. Two researchers observed the two street crossings (see Figure 2.4, A and B) by taking field notes, sketches, pictures and video clips. One researcher monitored two street signs, and this during different time slots (i.e. 8-9am, 11am-1pm, 3-4pm and 5-6pm) and during five days (i.e. weekend, Monday, Tuesday and Wednesday) We noted all the people who passed the sign, including people walking without looking; people who threw a quick glance; and people who stood still to 'read'. Occasionally, we conducted semi-structured interviews with those passers-by that actually 'read' the display to measure their understanding and interpretation of the visualization. In total, we observed 299 people and accomplished 24 interviews with 35 people. Almost half (N=16) of the interviewees were residents of one of the four streets, while seven interviewees were not inhabitants of the city.

**Post study interviews.** We then conducted follow-up interviews with the same 20 participants of the pre-study, mostly asking the same questions to measure any gain in local knowledge gathered through the urban visualization, and any change in perception towards the existing local concerns. These participants were also invited to express their personal opinion on the usefulness and attractiveness of the Street Infographic signs, and to raise other potential social issues and opportunities to visualize.

## 2.4. Results and Discussion

In this section, we will present the results of the Street Infographics case study and discuss the local and social potential of urban visualization.

**Local and Social.** The type of content provoked distinct expectations (e.g. "*First, I read something about immigrants and I thought it was propaganda*"), which in turn attracted passers-by to read (e.g. *"This made me come closer and read the sign. Then I noticed it was about students and residents"*). When interviewees reported what they had seen, their responses went beyond stating a data fact or trend, as it was always followed with some sort of reflection (e.g. "*I didn't expect this beforehand*") or opinion about the visualized issue (e.g. *"This is not the case in my street", "It is good to know there are still a lot of permanent residents" or "Students cause nuisance"*). This opinion was often followed with an anecdote about their personal experience with the issue (e.g. *"Once, it got out of hand [...]"*), or their self-awareness towards the issue (e.g. some respondents felt ashamed about their opinion on the rising student population issue). In the post study interviews, residents (N=6) requested to display urban visualizations of demographic data, such as the amount of (young) families and children or the age distribution in their street, as they felt this could deliver further surprising insights.

Accordingly, an urban visualization causes more than just the communication of data. Its impact can be unexpected and rich in interpretation, in particular when it addresses a contested, relevant issue for the local community. Unfortunately, an urban visualization has also the inherent danger to be misinterpreted, or be considered propaganda or advertisement. Therefore, we suggest involving the neighborhood community beforehand, such as by using a participatory design approach.

**Aesthetic and Medium.** An average of 31% (N=94) 'views' were registered, whereof 47 reads (i.e. 1 out of 2 stood still). This observation corresponds to previous findings in literature (Huang, Koster and Borchers, 2008), in that public displays attract a relatively low attention span, especially those that are not are located on eye height or accompanied by other means that attract attention. Remarkably, the number of views during the first time slot of installment (Saturday, before noon) was much higher (20 out of 32, or 62%) for both observation posts. Our semi-structured interviews with passers-by revealed that most 'readers' on that particular moment tended to be residents of the given streets, who were probably more sensitive to changes in their everyday environment. Although the interviewees were not informed about the installation of the signs before the study, all indicated the signs were unobtrusively integrated in the (urban) environment, yet, they could "feel" that some detail had changed (e.g. "*I sensed a larger blue area in the corner of my eye*").

Accordingly, we have discovered indications that even minimal, subtle interventions in the urban environment can successfully draw the dedicated attention of passers-by, and in particular those that know and frequent the environment well. This integration 1) conveys its explicit relationship and relevance to the immediate environment and 2) is recognized as having intrinsic value, in terms of communicating information (instead of marketing), as well as in enriching the experience of its surroundings in an unobtrusive and aesthetic way.

**Insightful and Persuasive.** Passers-by (N=35) who finished reading and continued their journey were asked about "what they have seen". From their answers, we can conclude that most passers-by correctly understood the visualization. Seven people described the exact percentages that were visualized in an explicit (e.g. "*12% are students*") or implicit way (e.g. "*5 out of 12 students are foreigners").* More than half of the people interviewed (N=19) referred to the data in more generalized terms (e.g. "*There are much more residents than students in this street*"). In the post-study interviews, we discovered that everyone who had noticed the sign (11 out of 20 residents), also had read and remembered the information correctly. Other anecdotal reports about the effect of the signage included how one resident had taken a photo of the display in order to present it to his neighbors of the next street. He used it as proof to demonstrate the high amount of students living in his street (i.e. 61%). Two residents stated their opinion in relation to the student population composition had changed in a positive way. One young woman mentioned the problems with students were not as bad as she declared in the first interview. She felt ashamed about her overestimation of the amounts of students (i.e. 80%) in the pre-study versus the displayed and correct amount of 31% students. An international student was surprised of the unbalanced student population in her street (i.e. 61%) and stated to now be "*more understanding towards permanent residents [...], because they are the minority*".

An urban visualization can be understandable for all, yet allow for sense-making, but also for personal interpretation and reflection. Urban visualization therefore differs from advertising or propaganda in its foundation to show data in some 'objectified' view that informs, but does not seduce. Its goal is not to convey a preference or ideology within the complex social, cultural, political and economic ecology of urban life. Instead, it should allow people to resist or sustain its meaning on their own terms, in order to allow for the emergence of a range of shared interpretations that are founded in generally agreeable data patterns. However, probably due to its opportunistic nature, it seems that the complexity of the resulting insights (e.g. combining more than one variable) is relatively limited.

**Contextual.** When the observed viewers had carefully 'read' a single visualization, about half of them actively searched for any other street signs in order to compare, proving an active process of understanding and sense-making. All onlookers correctly related the information shown to the correct street. Some people connected the location of the sign with the accuracy and credibility of the data (e.g. "*These numbers must be official, it is part of the street sign!*"). The deliberate integration of existing, meaningful elements of the environment as a part of the visualization can be useful to convey the situatedness of the information, as well as convey qualitative issues like trust and authenticity.

The meaning of an urban visualization may not be immediately understandable; instead, it can be discovered through reflecting on the nature of how the data is embodied in a physical form. In fact, it is often the act of reflecting that brings forward unforeseen associations, which can then be considered as 'insights'. This consideration permeates through its complete physical presence: from its location (e.g. what is the role of the building it is attached to?) and direction (e.g. where does it point to?) to details like the typography or the iconography. Consequently, an urban visualization requires the existence and the functionality of the surrounding context to co-exist; by separating them, the visualization will loose its meaning. This harvests a potential danger, people without contextual knowledge (e.g. people from a different culture, from a different city who do not know the inside of certain buildings) can misunderstand the visualization. Also, context can be limiting since not all meaning captured in data can be related to a physical space. The public acceptance and endurance of the visualization (none of the signs were vandalized or removed) was probably supported by its ambiguous purpose, as people were unsure the signs were actually art, propaganda or some official campaign.

**Opportunistic.** The visualization did not interfere with everyday life of the city, as people that were preoccupied (e.g. by jogging, talking on the phone, rushing to work), passed by the signs without obstruction. On three occasions, the view on one of two signs was obstructed by trucks that were unloading which implicitly caused distraction from the other sign as people had to deviate from their "normal" pedestrian flow. We observed people who first threw a quick glance at one infographic street sign, and walked back to read (see Figure 2.6). When people were grouped (2 or 3 persons), often one of them persuaded the others (e.g. by calling them back, by taking their hand) to stop and read. Others appeared to be determined, walking single-minded to the sign. Two interviewees, who declared to come back for the second time, brought someone with them (e.g. her son, her friend) to show the sign and share insights. Also, as identified by prior research (Brignull and Rogers, 2003; Ojala, Kukka, Lindén, Heikkinen, Jurmu, Hosio and Kruger, 2010; Memarovic, Langheinrich, Alt, Elhart, Hosio and Rubegni, 2012; Müller, Walter, Bailly, Nischt and Alt, 2012) a single onlooker often caused a *honey pot* effect that encouraged more people to stop and observe the sign, creating emergent social interaction between locals, sharing insights and opinions.


Figure 2.6 Passer-by notices augmented street sign Mussenstraat, walks towards and reads.

Urban visualization can thus be present in an urban environment without interrupting everyday activities, yet provide sufficient clues for those interested to actively engage in a sense-making process. This is a particularly complex matter when visualizing abstract information, as its graphical depiction should be immediately and intuitively understandable for all.

**Trustworthy.** We observed several onlookers searching for signs of authorship, for instance by looking at the back of the sign. The vast majority of interviewees (N=22) asked whether the information shown was up-to-date. Two residents even believed the sign would be updated daily by adding more or less stickers of figures (e.g. "*We come here every day to check if the amounts have increased"*). Also, several issues were raised about privacy (e.g. "*What about our privacy when information is publicly displayed?*") as well as about content (e.g. "*Is it ethical correct to display nationalities?", "Aren't you stigmatizing students by displaying their amounts?*"). Although we attempted to only display factual information in an objective way, several interviewees (N=10) thought the signs had a negative connotation by attracting attention to the actual prevailing issues, whether it was towards students or foreigners, instead of providing distraction from these issues.

Urban visualization puts "problems out in the open", available for those who are familiar with the presented issues, as well as those who might still have been unaware. This fact has led us to question the existence of "objective" visualizations when being deployed in public space. Even just presenting the data in public might be interpreted as a political act, so that it becomes a necessity to declare or proof the authenticity of the data source. Such form of disclosure can offer useful cues into reflecting on the visualization, and engaging with the issue at hand. Also, one must be aware of the local governmental laws that in all probability will expect explicit permission when using any kind of display in public space, let alone one that is contextually integrated in urban furniture. In addition, one should be well aware of the perceived intentions of publicly presenting previously little-known, yet possibly provoking information, in that the visualization might become a potential instigator of future actions surrounding local issues. At the same time, the immediate and public availability of the data underlying existing local issues seems to provide curiosity and constructive involvement with local residents.

## 2.5. Conclusion

In this chapter, we investigated the social and public potential of data visualization within the context of the public environment, guided by the principles of urban visualization. Our research was driven by a relatively simple design that combines the physical, social, visual and content features of an urban, physical environment and its identity, captured by data. Although we acknowledge that our observations have taken place within a single neighborhood over a limited period of time, our case study should be considered one of the first steps towards a better understanding of the true potential of using urban visualization for local and social purposes. Further research is required, however, to determine whether its impact on people's awareness or attitudes is sufficient to contribute to some of the important requirements of the envisioned smart city, such as transparent governance and responsible citizenship. Here, we believe that a more open and participative design process might lead to new findings. However, our intervention, coined Street Infographics, already provoked several encouraging reactions of locals and passers-by: curiosity, personal reflection, social interaction, perceptional changes, discussion amongst residents and the increase of public knowledge of social issues. It is still an open question, however, whether a more dynamic or higher-resolution display would be able to broaden the complexity of the insights and reflections.

# 3. Case study II – Sight on Local Data

This chapter consists of two sections: the first section seeks an answer on RQ2 by focusing on tangible and spatial dimensions of the interaction design of urban visualization. In the second section, we investigated a novel evaluation methodology for in-the-wild deployments, which is in particular relevant when aiming to study insights.

## 3.1. Sight on Local Data

This study is published as

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Presented at PerDis'15 conference on June 12, 2015 in Saarbrucken, Germany.

## My role

*Flanders DC, a contact point for creative entrepreneurs planned to organize a one-day event on 'the city of ideas' in Leuven, Belgium. I contacted them to offer them the opportunity to set up a public visualization on open data of Leuven. The resulting installation functioned as a pilot for the following study.*

*The pilot installation was painted white, while the final installation was bright red. Red is a signal color in the urban environment, thereby causing the final installation to look more integrated than the white version, while also causing the final installation to stand out.*

*I designed and constructed the installation, and executed the observations.*

*The publication was authored primarily by myself, with support from Andrew Vande Moere.*


Figure 3.1 The Sight on Local Data installation is presented to visitors of a one-day event of Flanders DC in May 2014.


*Figure 3.2 Detail of Sight On Local data during the pilot study*

## Abstract

*A rising number of public displays are becoming equipped with tangible interfaces. Especially in the context of the visualization of data in the public realm, offering tangible interaction modalities might actively attract and engage passer-bys, and lead to increased information discovery.. We therefore present a novel public visualization installation that deploys different forms of tangible interaction in combination with a public display in order to communicate civic data to a lay audience. During a comparative, deployment-based study in an urban context, we compared three distinct tangible interaction modalities in terms of the types of engagement and insight generation they facilitated. We report on our findings and discuss a number of design recommendations for tangible interaction on public information displays.*

### 3.1.1. Introduction

In the last few decades, an increasing amount of information has been released in the public domain, motivated by social movements in favor of transparency, and open or participatory e-governments. Moreover, various citizen initiatives have used the right to access and reuse public information as strategic tools for political influence and social action. The graphical representation of such data has already led to several significant changes in legislation, and has encouraged debate, changes in public opinion, and different forms of citizen participation. However, we believe for a participative tool of this nature to have a wider reach, it must be designed in a way that it fits into the existing communicative ecology of citizens. For instance, citizens should be offered the chance to become aware with locally relevant data in a situated (e.g. geographically located) and opportunistic (e.g. no required additional efforts) way, so that obvious usability and usefulness issues of currently existing approaches such as mailings, websites, or smartphone applications can be overcome. Using visualization in the public realm as a persuasive tool for informative and participatory goals has been accomplished before, yet most such initiatives have focused on realistic or experiential simulations of potential outcomes. Placing data-driven visualizations in the urban environment is a more opportunistic way of reaching citizens with abstract information (Vande Moere and Hill, 2012), such as facts and statistics. The practice of public visualization, i.e. the situated visualization of (often civic) data, has been used to encourage passers-by to engage with and reflect on trending civic challenges (Koeman, Kalnikaite, Rogers and Bird, 2014) or participate in them, e.g. via tangible user interfaces (Behrens, Valkanova, gen. Schieck and Brumby, 2014). However, citizens seem not eager to interact with infrastructure in public outdoor settings (Koeman, Kalnikaite, Rogers and Bird, 2014), unless to accomplish immediate goals, such as when consulting a bus schedule or a local area map. This behavior is often caused by 'interaction blindness', the inability to notice interactive features of a display or device in an otherwise busy or cluttered environment (Ojala, Kostakos, Kukka, Heikkinen, Linden, Jurmu, Hosio, Kruger and Zanni, 2012). In contrast, it has been shown that tangible interfaces are able to lure more visitors to interact than traditional mouse-and-keyboard setups (Horn, Solovey, Crouser and Jacob, 2009), at least in the semi-public setting of a museum. Accordingly, large, physical baubles, buttons or sliders seem more effective to attract the attention of passers-by and encourage them to interact with an interface in a public context (Taylor, Marshall, Blum-Ross, Mills, Rogers, Egglestone, Frohlich, Wright and Olivier, 2012; Koeman, Kalnikaite, Rogers and Bird, 2014). Similarly, so-called tangible 'curiosity objects', i.e. physical artifacts that are specifically designed to motivate inquisitive human behaviors, have been shown to overcome interaction blindness to some degree (Houben and Weichel, 2013).

For public visualization, encouraging people to interact with a display medium forms only the first step towards the discovery or exploration of specific information. Accordingly, as a passer-by interacts with physical, tangible objects, these can act as an interface that facilitates the exploration of specific information (Dourish, 2004). We hypothesize that tangible interaction is more effective in motivating passers-by towards information exploration in a public setting than traditional display media. Put differently, tangible forms of public visualization can more efficiently overcome the three stages of user engagement, ranging from *the passive engagement* over *active engagement* phase, into the *discovery phase* (Memarovic, Langheinrich, Alt, Elhart, Hosio and Rubegni, 2012). In this paper, we define tangible interaction as an interface that can be controlled by manipulating physical objects. Moreover, as tangible interaction generally means one needs to move objects around or one needs to move oneself (Dourish, 2004), tangibility adds a certain form of effort to the overall interaction process, which in itself might engage the passer-by more profoundly, or for a longer time. Within this context, recent studies in the domain of information visualization (infovis) have demonstrated that longer user engagement in casual (online) contexts, contribute to more learning (Sprague and Tory, 2012). One of the goals of public visualization is to encourage reflection of the information displayed (Vande Moere and Hill, 2012), such as discovering and reasoning about potential correlations between different phenomena captured in data, and their repercussions to one's personal situation. Such deeper insights are based on more than just reproduction of simple numbers or facts, and instead tend to require comparing multiple data dimensions in order to accommodate more analytical forms of inquiry; i.e. making comparisons, identifying trends, correlations, or potential causalities (Tufte, 2006). However, probably due to the opportunistic nature of public visualization, the depth of the resulting insights is relatively limited (Claes and Vande Moere, 2013).

Our research questions are twofold: (i) what is the impact of tangible interaction on public visualization displays?; and (ii) how do different forms of engagement affect the depth of insight discovery? Tangential to these goals, we will also study which kinds of civic information citizens explore in public settings. We will thus present the design rationale and in-the-wild deployment of a novel public visualization installation that combines a public display with different forms of tangible interaction that aims to unlock local civic data to a lay audience. To test our hypotheses, we deployed a between-subject study of three different tangible interaction methods in an in-the-wild setting.

This study is complementary to (Claes, Wouters, Slegers and Vande Moere, 2015), in which we proposed a novel, 'controlled' in-the-wild evaluation methodology. Instead of identifying and analyzing differences and qualities between methodologies, this paper reports on the design rationale, more detailed results as well as discussion of the evaluation study, which is synthesized in four design recommendations for tangible interaction on public visualization displays.

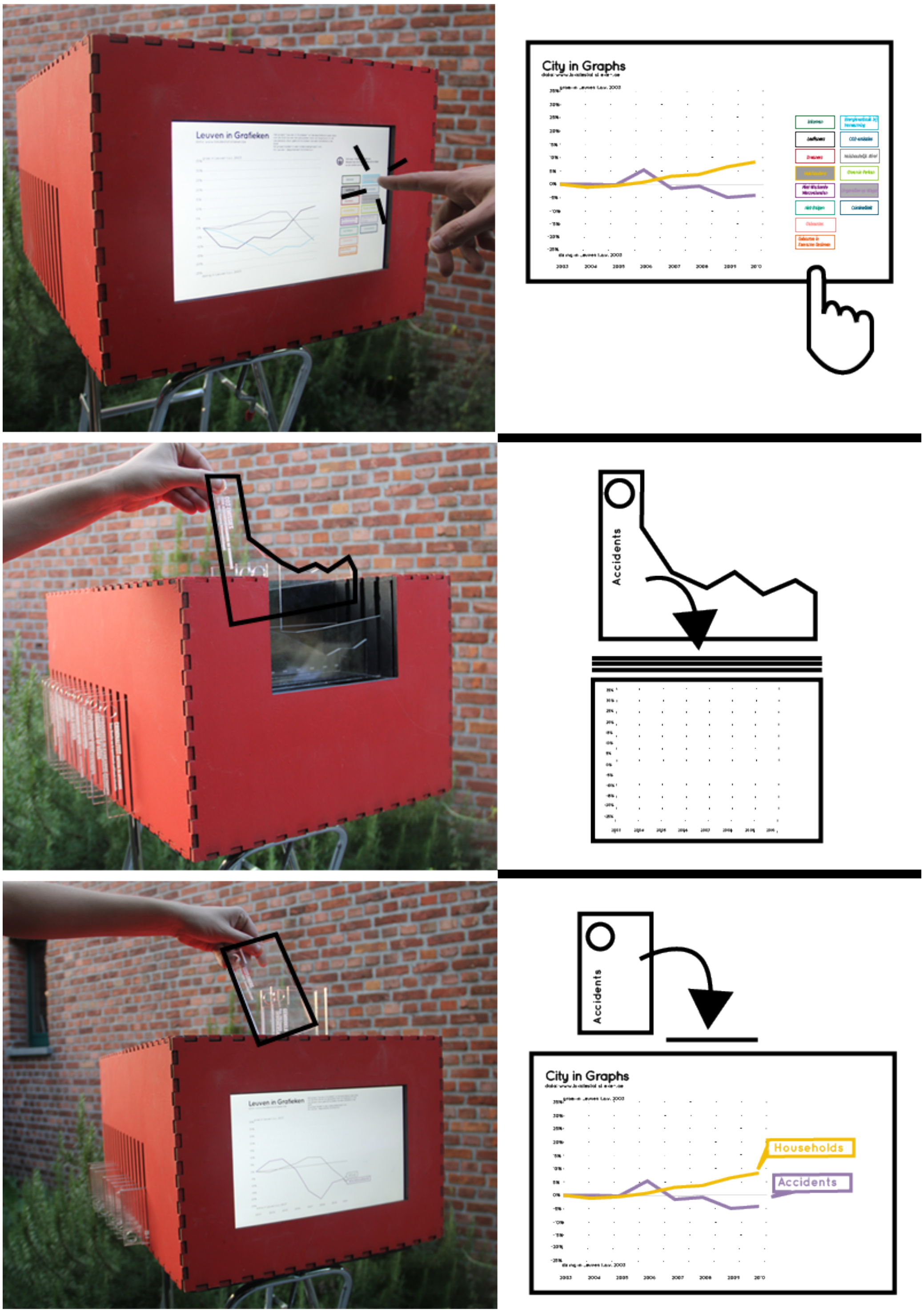


Figure 3.3 Condition touch (top), condition physical (middle) and condition mixed (under). Note the touch display buttons (top, right), the series of plates (middle, right)) denoting a data dimension of which 3 could be slotted at the top of the installation. The third condition mixed (under, right) combines a display (touch interaction is disabled) with plates.

### 3.1.2. Related Work

Because of recent technological advances (e.g. digital fabrication labs, affordable hardware, etc.), more public visualizations are integrating tangible instead of gestural forms of interfaces. The *smart citizen sentiment dashboard* utilized a tangible user interface to express their mood on local urban challenges, which was simultaneously displayed as a star chart visualization on a large media façade (Behrens, Valkanova, gen. Schieck and Brumby, 2014). The project *Fair numbers* visualized qualitative data as noisiness and crowdedness by means of a non-digital information display. Tangible elements on the display such as textures and shapes attracted passers-by and stimulated engagement with the information (Koeman, Kalnikaite, Rogers and Bird, 2014). Another quality of tangible interaction is its ability to make the public installation more situated, while lowering the barriers for participation, as demonstrated in *Street Talk* (Taylor, Marshall, Blum-Ross, Mills, Rogers, Egglestone, Frohlich, Wright and Olivier, 2012).

The tangible elements of these projects seem to add a certain playfulness to the traditional concept of public display. In information visualization, playing, as well as learning, has been recognized as a specific intrinsic motivation for users to interact with an information interface in casual contexts for a longer time (Sprague and Tory, 2012). For instance, users tend to be motivated to spend more time on a casual information visualization by way of extrinsic qualities, such as being bored (e.g. waiting for someone or something), having social pressure (e.g. with friends) or waiting (e.g. at the bus). Notably, most of these environmental qualities can also be recognized in an urban context.

### 3.1.3. Design

The external design of our public visualization (Figure 3.2) metaphorically referred to an urban telescope. The metaphor of a telescope was chosen to encourage passers-by to look 'through' it, and thus further interpret the environmental context of the surroundings, hereby suggesting that the displayed information is immediately related to the environment it is situated in. The physical appearance of the telescope was designed to look part of the urban furniture, in terms of color scheme (i.e. bright red to resemble urban signage), waterproofness (i.e. not bare wood but a painted surface) as well as robustness (i.e. heavy weight). The exterior of the installation was 1.80 meters high, 0.30 meters wide and 0.60 meters deep.

The default interface consisted of a title "*This city in graphs*" and conveyed data labels (i.e. X and Y axis, baseline). The visualization allowed the passer-by to explore 15 different line graph diagrams that each represented the percentile change from 2007 till 2013 of different local, civic data dimensions. These dimensions included: local social data, such as the number of births, births in disadvantaged families, inhabitants, households, foreigners, average income, unemployment, and citizens depending on social security; energy consumption data, such as energy usage, $CO_2$ emissions and waste management; and criminality data, such as traffic accidents and number of thefts. The telescope was specifically designed to encourage the simultaneous combination of up to three different data dimensions. This way, the resulting visualization revealed the temporal differences and thus potential correlations of up to four data dimensions, as time can be considered as an additional data dimension. By explicitly allowing the free combination of multiple data dimensions, sense-making, insight generation and personal reflection were meant to be implicitly encouraged. For instance, the line graph representing the decline of energy usage over time could be interpreted without any other context, or could be compared with the increase of population, which actually shows a trend of continuous energy reduction when calculated per citizen.

Table 3-1 Type of display and interaction of the three conditions.

| | Display | Interaction |
|---|---|---|
| **Condition *touch*** | Digital display | Touch |
| **Condition *physical*** | Non-digital display | Plates, shape of charts |
| **Condition *mixed*** | Digital display | Plates, one shape |

### 3.1.4. Study Design

First, a one-day pilot study was deployed during a local urban event, in order to evaluate general usability issues, such as whether people would actually perceive the visualization, are sufficiently intrigued by it to interact with it, and in how far they would understand it. We interviewed 25 people who interacted with the visualization, from which we were able to conclude that the installation appeared to be attractive and self-explaining, and facilitated the creation of valuable insights. We also discovered several flaws in its physical appearance, which lead to painting the inside elements black for more visual contrast, and lowering the foot to allow easy access for young children.

In order to compare the effect of tangible interaction with other forms of interaction, we implemented two additional modalities for the same overall installation. Our installation thus accommodated three different experimental conditions: (1) *touch*; (2) *physical*; and (3) *mixed* (see Table 3.1). For all conditions, precise instructions were provided on the telescope in the local language, below the display area.

Table 3-2 Results of the video analysis and interviews in (C)ITW

| | *Touch* | *Physical* | *Mixed* |
|---|---|---|---|
| Controlled in-the-wild study (CITW) | | | |
| Total passers-by | 14 | 12 | 16 |
| Interviewees (N) | 8 | 8 | 8 |
| Avg. interaction time | 2’55” (**σ**=1’40”) | 4’42” (**σ**=2’01”) | 4’15” (**σ**=1’20”) |
| Avg. age | 42 (**σ**=11) | 38 (**σ**=11) | 32 (**σ**=13) |
| Insights (amount) | 30 | 38 | 26 |
| Insights-per-participant | 3,75 (SD=2,43) | 4,75 (SD=4,06) | 3,25 (SD=1,48) |
| In-the-wild study (ITW) | | | |
| Total passers-by | 134 | 155 | 130 |
| Passively engaged | 31 | 54 | 41 |
| Actively engaged | 8 | 27 | 19 |
| Interviewees (N) | 4 | 14 | 7 |
| Avg. interaction time | 49” (**σ**=27) | 1’40” (**σ**=45) | 2’05” (**σ**=55) |
| Avg. age | 37,5 (**σ**=5) | 32 (**σ**=9) | 30 (**σ**=17) |
| Insights (amount) | 5 | 19 | 8 |
| Insights-per-participant | 1,67 (SD=1) | 2,39 (SD=1,1) | 2 (SD=1,41) |

**Condition Touch.** In condition *touch*, the telescope held a small digital display (30x40cm), i.e. a tablet computer that displayed the interface. Interaction occurs via buttons shown on the touch-enabled display, which stated the data dimensions (Figure 3.3, top). When clicked, the corresponding graph was displayed on the interface. A maximum of three data dimensions can be selected and shown as line graphs simultaneously.

**Condition Physical.** In condition physical, the telescope held a non-digital display, which conveyed the data labels (see Figure 3.3, middle). Interaction occurred via selecting, withdrawing and inserting TP plates on the side and on top of the telescope. Each line graph was laser-cut out of a transparent thermoplastic (TP) plate (30 x 30 cm). As such, the plates had the physical shape of a line graph. Each plate stated the title of its data dimension and its original source (e.g. Local Government). The 15 plates were arranged in 15 slots on the left side of the telescope. The top of telescope featured three open slots, which allowed visitors to insert individual physical plates, to look through the telescope as well as the transparent plates, and to subsequently compare the different data dimensions on display.

**Condition Mixed.** Condition *touch* combines aspects of both *touch* and *physical*. In contrast to condition *physical,* this condition was designed to be more sustainable and general applicable, as the data dimensions are shown digitally and thus do not require any separate physical construction. The telescope held a digital display (with an identical interface to condition *touch*), and its plates were uniform in shape. Up to three distinct data dimensions could be inserted in the slots above and then were shown on the digital display (identical as in condition *physical*). Technically, each of these plates was uniquely identified by way of hall effect sensors in each slot that recognized the presence of hidden, small magnets in each plate.

The study consists of two distinct parts: (1) an in-the-wild field study; and (2) a controlled in-the-wild study (Claes, Wouters, Slegers and Vande Moere, 2015), in which we compare and analyze the impact of tangible elements on engagement and insight discovery of a public visualization in an urban environment.

1) *In-The-Wild (ITW).* In order to provide comfort spaces to support a passerby to explore the visualization from a distance while allowing plenty of potential interaction space (Fischer and Hornecker, 2012), we chose two distinct public locations to deploy our visualization; (1) a public square functioning as a heavily frequented passage to a bus and train station; and (2) a traffic-free shopping street with benches and trees in the middle, which allows people to rest. At each location, the public visualization was installed during two consecutive days (six hours per day). To avoid obvious learning effects, we changed the conditions in random order. During installment, a researcher observed the public visualization. A video camera was located in the vicinity of the public visualization to record all actions in an area of 5 meter around the visualization during the installment period. The camera's wireless microphone was concealed inside the telescope, and captured the utterances of passers-by. In conditions *touch* and *mixed*, all interactions were also electronically logged. After a passerby interacted with the installation, the researcher would approach her for a semi-structured interview to question her insights, motivation to interact, experience, and her demographic information.

2) *Controlled In-The-Wild (CITW).* To learn the reasoning behind the generated insights and find out why people selected certain data dimensions, we deployed a new evaluation method, i.e. controlled in-the-wild study (Claes, Wouters, Slegers and Vande Moere, 2015). In short, this method consists of mimicking the spontaneous character of an in-the-wild situation: participants are invited beforehand, the experiment occurs in an ecological valid – yet controlled – environment, while all user behavior is measured in absence of the researcher(s). We have set up the installation at two locations, each during one day in an outdoor environment, i.e. two passages of the university campus near the city. Local university personnel that were also citizens of the city (and thus knew the context of the data) were invited via email to participate in an "open study on interactive installations". Individual appointments were made with total of 30 people, which were asked to keep 30 minutes available of their personal time. Before the experiment started, the researcher introduced herself, but not the project. She then left the person alone with the public visualization mentioning an everyday excuse (i.e. toilet break). From that moment on, the participants were thus free to engage with the visualization (or not). When the researcher returned, a semi-structured interview was conducted. This approach allowed us to observe any spontaneous behavior in an ecological valid environment, while retaining better control of participant involvement, and avoiding frequent visual or auditory obstructions.

**Engagement analysis.** After the installments, a researcher analyzed the video footage by coding all actions of each passerby. When a passer-by engaged with the installation, we recorded the time spent in any of the three engagement zones around public displays, i.e. the passive, active and discovery phase (Memarovic, Langheinrich, Alt, Elhart, Hosio and Rubegni, 2012). We coded passers-by as 'passively engaged' when they read or looked at the display from an area of two to three meters from the installation, and/or interacted briefly (i.e. one touch and then left). 'Active engagement' was recognized when passers-by interacted with the installation for a longer time.

**Insight analysis.** In order to study the type and depth of the insights passers-by gained, an insight reporting methodology was used (Saraiya, North and Duca, 2005; North, 2006). Accordingly, interviewees were invited to report "*what they had discovered in the data*". This question was formulated in such a broad way to encourage participants to report any resulting finding without assessing its potential value or usefulness. After the study, two independent researchers coded the collected insights on an *insight scale*. This scale was divided in three distinct subcategories of *insight depth*: (1) *factual*, a mere description of data values, e.g. "*the number of inhabitants has raised*"; (2) *interpretive*, the synthesis of data values with objective knowledge or an existing experience, e.g. *"the number has raised yet in 2008 there was a sudden decline*"; and (3) *reflective*, which is similar to interpretative, yet contains some subjective, or emotional connotations, e.g. *"the number has raised, which is normal because I can literally see the city is growing".*

Figure 3.4 Passerby ITW interacts in condition physical.

### 3.1.5. Results

**From passive to active engagement** During ITW, we noticed how passers-by (N=6) in condition *physical* almost skipped the passive engagement phase and immediately (after glancing at the installation for 1 or 2 seconds) were actively engaged by grabbing a plate, and reading its contents. Then, they inspected the installation for instructions. Although the condition *mixed* had the identical set up with plates, passers-by seemed more hesitant to grab one. This hesitant behavior also occurred in CITW. Here, all passers-by in condition *physical* proceeded more quickly (1”(**σ**=1”)) to grab a plate than in condition *mixed* (4”(**σ**=2”)), and also faster than clicking a button on the touch screen (2”(**σ**=3”)). Interviewees of condition *touch* and *mixed* revealed they first read the instructions, while in condition *physical*, passers-by (N=6) recognized the shape of the plates as ‘puzzles’, which intrinsically encouraged them to play around and discover how the installation functioned. All passers-by claimed they interacted because *“they were curious what it was about”.*

**Active engagement and social triangulation** We noticed the honeypot effect particularly during condition *physical,* which in all four occasions resulted in cooperation between strangers (N=8). In three of those occasions, we noted how one passer-by interacted with the display and the plates on top of the telescope, while a second passer-by looked into the row of plates, and compared charts without inserting them in the telescope. In these occasions, the simultaneous exploration of plates also acted as a conversation starter. In the video analysis, we further noticed how the plates of condition *physical* were studied without inserting them in the telescope (e.g. by piling two plates on top of each other and holding them to the light) and that passers-by stood around at various locations around the telescope (in contrast to conditions *touch* and *mixed*, which were always manipulated at the front). Also, the plates were distributed along the left side of the telescope in condition *physical* (and *mixed* to a lesser degree), which revealed the affordances from different angles and engaged them for a longer time, as passers-by (N=5) would walk towards, pass the display, notice the plates and then stop to grab a plate.

**Information discovery** In ITW, the insight analysis revealed condition *touch* did not evoke comparisons between data dimensions (only within one dimension, e.g. "*the population has increased"*), while the condition *physical* (4 out of 19 insights) and *mixed* (2 out of 8) allowed for comparison between two dimensions (e.g. "*population has increased because there were more births"*). In CITW, this observation was also apparent, yet more insights were reported in general (94 insights versus 32 in-the-wild). However, in conditions *physical* (7 out of 38 insights) and *mixed* (3 out of 26), passers-by also made deeper insights that compared three data dimensions (e.g. "*population has increased because there were more births and the income was higher"*). Passers-by who compared two or three data dimensions (N=18) often started with the choice of one data dimension and then actively explored a potential hypothesis, e.g. *"I took one chart and then selected other data to compare with"* or *"I saw the number of inhabitants had increased and wanted to find out if energy usage also had raised*"). In the 4 before-mentioned cases of social interaction with strangers in condition *physical*, the afterwards reported insights often searched for less evident relationships between the data, with often humorous results (e.g. *"We thought the increased amount of births would have influenced the amount of waste. All those diapers are heavy! But it appeared not to be the case since waste has declined*" or *"Energy consumption has declined while income has raised. This means people are getting richer by saving energy!").* Here, some interviewees (N= 3) stated they had combined their insights with those of the stranger.

However, although most interviewees (N=31) in all conditions stated to be playing around, they remembered well which particular data dimension(s) they chose. Four interviewees of condition *physical* deliberately "*did not select the number of foreigners because they did not want people to think that this kind of topic is an interest of them"*. Passers-by consciously chose mostly (65 of 126 reported insights) 'social' data, such as birth rate or population, 11 interviewees stated the choice for this data dimension was based on what they saw in their immediate surrounding (e.g. *"I don't know why I chose this [referring to number of births], but when I look around here I see a lot of children"*). In condition *physical*, some interviewees (N=4) based their choice of data dimension on the shape of the plates, e.g. 'number of births in disadvantaged families' had an abnormal large shape as the increase in caused the graph line to go 'off chart'.

### 3.1.6. Discussion

**Engagement.** During our observations, it appeared passers-by were most attracted to the visualization in condition *physical*, as they spent more time interacting and discovered deeper insights. The apparent physical properties of the visualization led passers-by to pass the passive phase into active engagement. However, although condition *mixed* and *physical* possessed identical tangible interaction modalities, they did not facilitate the same amount of engagement. As the conditions differed in tangible characteristics (i.e. condition *physical* had inherent tangible qualities that used touch to reveal the data without the need for the telescope, where condition *mixed* only revealed the dimension legend), it indicates the role of the physical design of the tangible elements to guide curiosity and allow multiple, simultaneous affordances. Furthermore, condition *mixed* also actively engaged more passers-by than condition *touch*, which confirms the curiosity-provoking capacity of tangible interfaces. This capacity also led to emergent and unforeseen interactions, such as handling the plates to compare data without the telescope. Moreover, the spatially dispersed interaction quality of condition *physical* (and *mixed* to a lesser degree) made the telescope approachable from different points in the immediate environment, which encouraged several passers-by to collaboratively engage with the information. A possible disadvantage of the physical plates is that they potentially encourage more misuse in terms of vandalism or stealing, although we did not observe these kinds of behavior. In addition, the explicit presence of a digital display in condition *touch* and *mixed* toned down the enthusiasm of passers-by to interact, as they wanted to read instructions before interacting.

*Design recommendation.* Tangible interaction elements succeed in attracting attention towards a public display, provoke curiosity and encourage passers-by to become actively engaged. When tangible interaction elements are able to stand on their own, i.e. have meaning independent from the display, they afford multiple ways of interacting with the information, which may appeal to a diverse audience. Also, physically distributing these tangible interaction elements around the public visualization display allows diverse collaborative and multi-user usage scenarios.

**Insight generating capacities.** Noticing and then engaging with a tangible interface in an active way are the first steps towards information discovery. In all conditions, passers-by were motivated to interact out of curiosity, i.e. "*what is this installation about?*". Although condition *touch* engaged as much passers-by in a passive way as condition *mixed*, it engaged less passers-by in an active way, which led to less reported insights per interviewee and the insights were mostly limited to one data dimension. In condition *mixed* and *physical,* the longer active engagement period allowed the passers-by to discover more and deeper insights.

*Design recommendation.* Actively engaging passers-by with information in public space can shift their extrinsic motivation, such as becoming curious or bored, to intrinsic goals, such as learning and reflecting about their local environment. Therefore, the design of a public visualization should reach a balance between making passers-by curious, and allowing them to accomplish personal goals without requiring external motivation, guidance or support.

**Type of data.** In condition *physical*, passers-by did not select certain 'sensitive' data dimensions, such as 'number of foreigners' or 'criminality', because they felt observed by others and did not want to be identified with implied meanings or preconceived ideas, which however limited their discovery to socially desirable information. Although our visualization did not respond to an immediate information need, it still succeeded to lure people into interacting with abstract and rather complex information. For the selection of data dimensions, some passers-by were inspired by elements of the environment (e.g. children in the street) or of the installation itself (e.g. shape of the plates).

*Design recommendation.* Allowing people to read and explore data in the public realm can be challenging in terms of assuring the privacy of the user interactions. In fact, interactions via tangible interfaces are even more visible and explicit than those via traditional (display) media, However, this limitation can also encourage more reflection on the data shown, the environment or the onlookers. It is still an open question how one can deal with this privacy tension in public interactivity. Furthermore, the (public) data shown should be carefully selected in terms of its meaningfulness, relevance and timeliness within the social, spatial and cultural realities of its immediate environment.

**Social interaction.** Conditions *mixed* and *touch* afforded only one person to interact with the visualization at a time. The spatial and physical qualities of condition *physical,* on the other hand, allowed multiple passers-by to engage with the information at the same time, as there were multiple tangibles available and each tangible could be interpreted without the help of the telescope. This way, strangers could explore information independently, while the trends they discovered provided them with starting points for conversation. Some people discussed and combined their personal insights with others, leading into compound insights.

*Design recommendation.* Providing different physical and tangible access points for people to interact with a public visualization supports various forms of social interaction. For instance, multiple passers-by can become encouraged to engage and even collaborate with each other in terms of sense-making and insight discovery by providing them with different modalities and views in the data.

### 3.1.7. Conclusion

In this paper, we designed and deployed a novel public visualization in order to evaluate three different tangible interaction modalities in a public context. We showed how tangible interaction can elicit different forms of engagement and generate more and deeper kinds of insights, when compared to traditional public display media. This study concluded with four design recommendations for the future design of (tangible) public visualization displays.

## 3.2. Evaluating Sight on Local Data in a controlled in-the-wild set up

This study is published as

Claes, S., Wouters, N., Slegers, K., & Vande Moere, A. (2015). Controlling in-the-wild evaluation studies of public displays. In Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (pp. 81-84). ACM.

DOI 10.1145/2702123.2702353 Acceptance rate: 23%

Presented at CHI'15 conference on April 20, 2015 in Seoul, South Korea.

## My role

Figure 3.5 shows a second pilot study that was not reported in the publications of this chapter. This second pilot installation was encapsulated to ensure visibility in heavy sunlight, as this was problematic with the initial, pilot installation. However, only one passers-by engaged during the 4 hour set up. Some passers-by that did not engage informed me they did not visit the installation, as they could not see the actual content from far. Also, being 7 months pregnant at the time, this installation was too heavy for me to install on a daily basis. I decided therefore to strip the installation to its original dimensions.

The publication was authored primarily by myself, with support from Niels Wouters, Karin Slegers and Andrew Vande Moere.

Figure 3.5 Taking a picture of the second pilot installation, at the Martelarenplein in Leuven.


*Figure 3.6 Sight on Local Data set up in condition mixed, in the Brusselse straat in Leuven.*

## Abstract

*In this paper, we investigate the potential of controlled in-the-wild studies as an evaluation methodology that merges the benefits of lab-based and in-the-wild studies. Our exploratory investigation builds upon a comparative, between subject experiment benchmarking different interaction features of a custom public installation that visualized a series of urban datasets. In order to evaluate the usefulness of the in-the-wild versus the controlled in-the-wild methodologies, we compared the resulting findings in terms of participant engagement, insight generation, and social interaction. We propose that a controlled in-the-wild study offers a viable alternative when evaluating more complex interaction methods in public space, hereby potentially reducing the practical efforts of in-the-wild studies to involve participants.*

### 3.2.1. Introduction

As interactive public displays increasingly permeate our urban environment, the need arises to evaluate their effectiveness in purposively engaging passers-by. Typically, longitudinal effects are studied in deployment based research, while early prototypes are studied in lab studies, which aim to minimize the impact of external influences (e.g. (Beyer, Alt, Müller, Schmidt, Isakovic, Klose, Schiewe and Haulsen)), or in-the-wild studies (Rogers, Connelly, Tedesco, Hazlewood, Kurtz, Hall, Hursey and Toscos, 2007), which preserve the ecologic validity of real-life contexts (Alt, Schneegaß, Schmidt, Müller and Memarovic, 2012). However, both lab as in-the-wild methodologies are faced with particular shortcomings (Kjeldskov, Skov, Als and Høegh, 2004), as lab studies fail to simulate the complex, unpredictable dynamics of the 'real world', and in-the-wild studies tend to be cumbersome in terms of participant commitment (e.g. limited time commitment), preparation (e.g. permits) and privacy regulations (e.g. video logging in public space).

We believe the opportunity exists to merge the qualities of lab-based and in-the-wild studies into a single evaluation methodology, i.e. "controlled in-the-wild studies". Although such methodology would retain ecological authenticity while also enjoying dedicated participant commitment and relatively few unpredictable organizational issues, little is known of its applicability or the validity of its results (Oulasvirta, 2009; Hornecker and Nicol, 2012). Therefore, we have compared the findings from an in-the-wild (ITW) and controlled in-the-wild (CITW) study in order to analyze the qualities and challenges inherent to each methodology. We used the findings of a comparative, between subject evaluation study of an interactive urban installation that compared the impact of three distinct conditions. Observations from each methodology are structured according to user engagement, the depth level of insight discovery, and any apparent social interaction (Memarovic, Langheinrich, Alt, Elhart, Hosio and Rubegni, 2012). We believe this knowledge is relevant for research that is highly dependent on real-life contexts, while yielding results in more efficient and flexible ways.

### 3.2.2. Case study

We designed an urban installation to inform passers-by of locally situated information. The urban installation had the shape of a telescope (see Figure 3.4), in order to metaphorically invite people to reflect on their environment by looking through a 'lens' of data. The data consisted of dimensions like local birthrate, total number of inhabitants, average income levels, total energy usage and total amount of waste produced by local households. As we preferred to encourage passers-by to simultaneously observe 3 distinct data dimensions, we felt unsure what interaction technique to deploy in a public setting. Accordingly, we developed 3 distinct conditions that differed in how people could select the 3 data dimensions, as well as the media on which the dimensions were shown, i.e. 1) *touch*, i.e. in which data dimensions were both selected and shown as graphs on a standard touch display; 2) *physical*, in which the data dimensions were shown as graphs on physical discs, which had to be selected by hand; and 3) *mixed*, in which the dimensions were selected by handling physical discs, yet the graphs were shown on a display. Our comparative experiment was thus designed to investigate if the *way* the telescope facilitated interaction influenced the passive and active engagement (Memarovic, Langheinrich, Alt, Elhart, Hosio and Rubegni) of passers-by, the depth of the discovered insights (North, 2006), and the social interaction alongside.

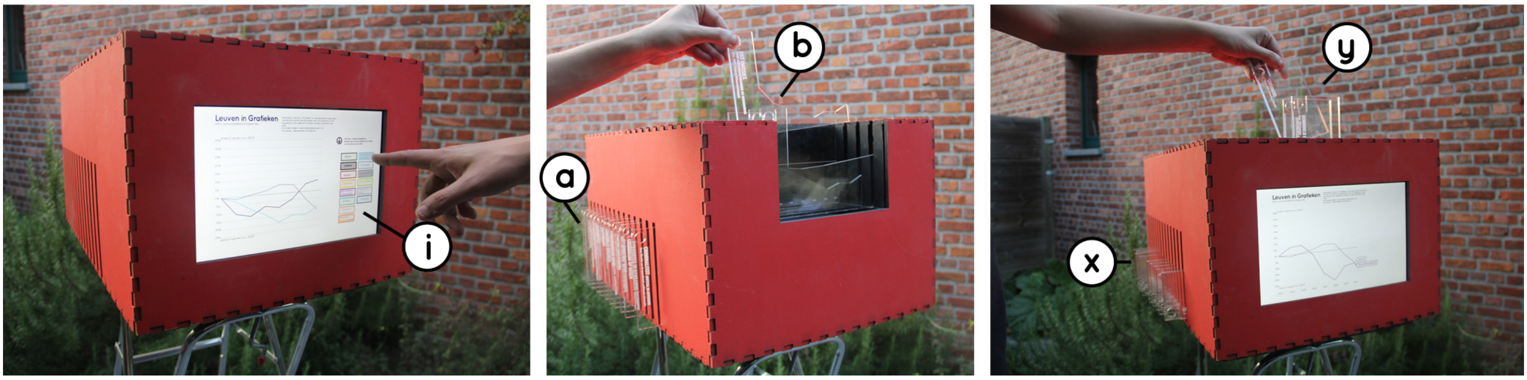


Figure 3.7 Touch condition (left), physical condition (middle) and mixed condition (right). Not the touch display buttons (i), the series of discs on the left side (a, x) denoting a data dimension each, of which 3 could be slotted at the top (b, y).

**Touch Condition.** People were able to select up to 3 different data dimensions by pressing common touch-enabled buttons that were displayed on a (30x40cm) digital screen (Figure 3.3, left).

**Physical Condition** contained no display. Instead, a series of transparent thermoplastic (TP) discs were provided on the left, outer side of the telescope, forcing people to solely interact in a tangible way (Figure 3.3, a). People could insert up to 3 TP discs in the 3 slots on top of the telescope (Figure 3.3, b). Each disc was specifically laser-cut to state a dimension, and physically resemble the matching line graph.

**Mixed Condition** featured the same display as in the *touch* condition (Figure 3.3, z), yet people could select up to 3 data dimensions in an identical way to the *physical* condition. The according data graphs were shown on the display.

Table 3-3 Overview of evaluation methods used in the in-the-wild and in the controlled in-the-wild methodologies.

| **Methods** | ***ITW*** | ***CITW*** |
|---|---|---|
| *Observations* | Y | Y |
| *Video logging* | Y | Y |
| *Semi-structured interviews* | Y | Y |
| *Spontaneous user participation* | Y | N |
| *User recruitment* | N | Y |
| *Between subject design* | Y | Y |

### 3.2.3. Methodology

Next to several other evaluation methods (see Table 3.3) both ITW and CITW involved semi-structured interviews in order to reveal: 1) why users engaged with the telescope; 2) how they interacted; and 3) what new insights they discovered. In addition, video fragments of each condition were analyzed by categorizing every passer-by according to the Passive, Active Engagement and Discovery (PACD) model (Memarovic, Langheinrich, Alt, Elhart, Hosio and Rubegni): passive engagement comprises of glimpses and glances towards the display, while active engagement occurs when passers-by read or interacted with the display. We also measured the time spent during each engagement phase, and analyzed the *depth* of each reported insight by counting the number of data dimensions that had to be put together to be able to reach the insight.

**In-the-wild Study (ITW)**

During the in-the-wild study (ITW) the telescope was deployed in 2 divergent locations: a pedestrian shopping street (Fig.2, right) and a square in a residential area, near a major bus stop. Passers-by were thus able to freely walk up to the installation and actively engage with it (or not). Each person who actively engaged with the installation was approached by a (previously concealed) researcher to participate in a semi-structured interview.

**Controlled in-the-wild Study (CITW)**

We set up the controlled version of the in-the-wild study (CITW) at the university campus nearby the city. Local university personnel (e.g. PhD students, administrative and technical staff) were invited via email to participate in an "open study on interactive installations". Individual appointments were made with interested persons who live, or lived, in the city (and thus knew the context of the data). They were asked to keep 30 minutes available of their time. The telescope was placed outside, at one of 2 different locations that resembled the characteristics of the in-the-wild environment. At the start of each experiment, the researcher introduced herself, but not the project. She then left the participant alone with the telescope mentioning an everyday excuse (i.e. toilet break). From that moment, participants were thus free to engage with the telescope or not, which was logged via a nearby video camera. The researcher returned after she noticed that the 'free' user engagement finished, and a semi-structured interview was taken, together with a Likert scale survey.

Figure 3.8 Passage (CITW, left). Shopping street (ITW, right).

Table 3-4 Demographic participant characteristics of (C)ITW.

| | *Touch* | *Physical* | *Mixed* |
|---|---|---|---|
| **Controlled in-the-wild study (CITW)** | | | |
| Duration | 4h | 4h | 4h |
| Passers-by | 6 | 4 | 8 |
| Participants (N) | 8 | 8 | 8 |
| Avg. interaction time | 2’55” (**σ**=1’40”) | 4’42” (**σ**=2’01”) | 4’15” (**σ**=1’20”) |
| Avg. age | 42 (**σ**=11) | 38 (**σ**=11) | 32 (**σ**=13) |
| Gender | 4M, 4F | 3M, 5F | 4M, 4F |
| Insights (amount) | 30 | 38 | 26 |
| Insights-per-participant | 3,75 (SD=2,43) | 4,75 (SD=4,06) | 3,25 (SD=1,48) |
| **In-the-wild study (ITW)** | | | |
| Duration | 4h | 4h | 4h |
| Passers-by | 134 | 155 | 130 |
| Passively engaged | 31 | 54 | 41 |
| Actively engaged | 8 | 27 | 19 |
| Interviews (N) | 4 | 14 | 7 |
| Avg. interaction time | 49” (**σ**=27) | 1’40” (**σ**=45) | 2’05” (**σ**=55) |
| Avg. age | 37,5 (**σ**=5) | 32 (**σ**=9) | 30 (**σ**=17) |
| Gender | 2M, 2F | 6M, 8F | 6M, 1F |
| Insights (amount) | 5 | 19 | 8 |
| Insights-per-participant | 1,67 (SD=1) | 2,39 (SD=1,1) | 2 (SD=1,41) |

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### 3.2.4. Results

**Passive engagement.**

*ITW.* Our observations indicate that the *physical* condition motivated 34.8% of passers-by (54 out of 155) towards passive engagement (see Table 3.4) *CITW*. During interviews, participants reported the "see-through aspect" of the display in the *physical* condition had attracted them to approach and look through the telescope.

**Active engagement.**

*ITW.* Out of 130 passers-by, 11 immediately grabbed a TP disc in the *physical* condition (avg. delay: 1" (**σ**=1), and analyzed its contents. Subsequently, they often searched for additional instructions on what to do next.

*CITW.* Participants in the *physical* condition revealed they were not hesitant to grab a disc because the installation "*looks playful*" and "*easy to work with*" (n=6). Participants in both other conditions revealed to be more cautious (n=11), mainly because of the perceived technical complexity (e.g. "*I might do something wrong*").

**Insight depth.**

*ITW*. In *touch*, participants compared multiple data dimensions, yet never reported any insight that contrasted 2 distinct dimensions. However, both *physical* and *mixed* seemed to motivate participants to explore the relationship between up to 2 dimensions, leading to deeper insights (e.g. "*more green leads to more criminality*", *mixed*).

*CITW* provided similar results. However, in *physical* and *mixed*, participants also reported comparisons between 3 datasets, the maximum number of possible combinations. During the interviews, almost all participants of *touch* (n=7) indicated they randomly explored the available dimensions, without hypothesizing a relationship between them. In contrast, in condition *physical* (n=7) and *mixed* (n=6), participants said they looked first at all possible dimensions available and then made a choice based on their personal interest to discover a specific relationship.

**Social interaction.**

*ITW.* We only noticed honeypot effects (n=4) between strangers during *physical*, such as discussions about the purpose of the telescope. The insights produced by social interactions between multiple passers-by were deeper.

*CITW.* In the *touch* and *physical* conditions, we noticed honeypot-effects when accidental passers-by asked participants about what they were doing (n=3). However, no insights were discussed with strangers, nor were they invited to join in. It was more evident in the CITW video log analysis that the discs were used without the display in condition *mixed*, and that participants stood at various locations around the telescope (in contrast to the display conditions, which were always manipulated at the front).

### 3.2.5. Discussion

By evaluating our comparative between-subject experiment results, we observed that many results of ITW and CITW overlap although they were derived by different evaluation methodologies. However, while ITW was more ideal to identify quantitative indications of actual user engagement, CITW yielded more valuable insights on *why* these trends were happening, which allowed us to evaluate the effectiveness of the interaction method.

**Participant Involvement**

Passers-by in public environments often decline to participate, due to personal time constraints or other social circumstances. They tend to answer only the first few questions willfully, then evade any prolongation of the interview by giving too concise answers, or answers that are socially desirable (e.g. *"The installation was very nice, thank you!").* Some participants respond in irrelevant ways, incorporating non-relevant topics (e.g. "*I think the city council […] should not spend time on this kind of stuff!").* Although ITW generally provided more participants in the same amount of time (4h), eliminating time and social constraints in CITW allowed us to explore the capabilities of the public installation more thoroughly and completely, as participants' answers were more considerate and better expressed. While the number of insights per participant was higher for CITW, ITW demonstrated the same insight distribution over the 3 conditions. ITW also showed that more passers-by interacted with *physical* than the other 2 conditions in identical environments. In CITW, we gained similar knowledge about popularity via interviews, yet also learned that this pattern was the result of the spatially distributed, low-tech and visually playful appearance of *physical*. As CITW supports full control over participant numbers and demographics, it allowed us to benchmark the 3 experimental conditions to each other. However, we remark that as the CITW participants worked in technical or administrative university positions, analytical feedback could have been exaggerated.

*CITW leads to more and better qualitative results, which tended to compensate for the lack of quantitative measures.*

**Ecological validity**

As with all in-situ studies (Rogers, Connelly, Tedesco, Hazlewood, Kurtz, Hall, Hursey and Toscos, 2007), CITW balanced the need to control realism and external factors by providing participants with a prescriptive task within a representative environment. Due to its (semi-) public setting, CITW still allowed for unpredictable situations to occur that could influence results, such as curious passers-by, unexpected phone calls, weather elements, or traffic conditions. However, CITW requires a particular research design that facilitates spontaneous participant behavior (e.g. researchers leaving the vicinity unsuspiciously). Ideally, CITW could simulate group-based social interaction by inviting multiple participants. Because of its full control over both participant demographics and social relationships, we propose that this research methodology lends itself well for further research on multi-user and social interactions.

*The public setting and absence of researchers allows still semi-realistic situations to occur in CITW, yet it requires a well-considered research design that artificially simulates spontaneous context of use.*

**Practical Matters**

ITW often necessitates obtaining many permissions, such as to occupy public space, survey or film passers-by, respect privacy concerns, or acquire the approval of private persons to use their property. As CITW avoided frequent visual obstructions of unengaged passers-by, its 'cleaner' video logs allowed for a more thorough and efficient analysis of participant behavior. Moreover, as most practical matters and permits can be incorporated from the research design stage, CITW lends itself well for deploying additional or more sophisticated behavioral logging methods. For instance, CITW could include 'fake' participants that might behave in particular ways, or one could deliberately shift between ITW and CITW methodologies to assure ecologically correct participant demographics.

*Overall, CITW allows for a more efficient yet controlled research context. Moreover, because of the overlapping results once participants are actively engaged, future ITW studies could consider skipping semi-structured interviews or detailed video analysis when circumstances are complex.*

### 3.2.6. Conclusion

We benchmarked an in-the-wild versus a controlled in-the-wild methodology in the context of a comparative between subject evaluation study. We analyzed their respective ecological validity, participant involvement and practical aspects. We discovered similar results although they were derived by different evaluation methodologies. Therefore, we propose that CITW offers a viable alternative when investigating the effectiveness of more complex interaction techniques in public settings. CITW allows researchers to work more efficiently in terms of participant involvement and the deployment of research methods, while the data is still gathered in relatively ecological valid, spontaneous context. However, we note that CITW should be considered complementary to ITW, as CITW is not yet ideal to capture ecological valid user engagements or quantitative results. In conclusion, as the field of public display progresses and its research questions are becoming more sophisticated, more research is required to investigate the true potential of CITW. For instance, it is still unknown how more complex user behaviors could be staged and analyzed while respecting ecological validity, whether ITW participants could be successfully invited to a CITW in order to increase participant demographics variety, or whether the (C)ITW results are actually representative of longer term usage.

# 4. Case study III: Bicycle Barometer

This chapter consists of 2 sections: Section 4.1 presents the design and development process of Bicycle Barometer as a high fidelity prototype, which is tested in two different contexts (RQ3). Section 4.2 presents an in-the-wild replication study on Bicycle Barometer as research product, in which we compare how material dimensions affect engagement (RQ0).

## 4.1. Design and development of Bicycle Barometer

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## My role

*The province of Vlaams Brabant asked our research group to design a new type of cycling counter display. Together with the city of Leuven and Mobiel 21vzw, they were involved in a project that aimed to track cyclists and their sentiments. The high fidelity prototype is constructed with the help of my husband, and was also designed to be light-weighted as I was 7 months pregnant at the time. On the technical side, we hired a programmer to translate data input to a visualization on the LED display.*

*The resulting publication was authored primarily by myself, with support from Niels Wouters, Karin Slegers and Andrew Vande Moere.*

Figure 4.1 Co-design workshop with cyclists and local government representative.


*Figure 4.3 Cyclist browsing voting options.*

## Abstract

*As cycling is increasingly promoted as an environment-friendly, cheap and even fast alternative, there exists an increasing need to civically involve the potentially engaged and opinionated user group of cyclists. Therefore, we designed and evaluated Bicycle Barometer, an interactive bicycle count display that gathers the opinions from cyclists and conveys real-time, multi-dimensional data to them regarding cycling behavior. Our user-centered design process focused on optimizing the user experience by comparing several alternative cyclist-specific interaction designs, which resulted in the combination of a pressure sensitive floor mat, push button and low-resolution LED display. An in-the-wild evaluation study resulted in a set of design recommendations for cyclist-specific interaction, providing concrete insights into how a specifically targeted interaction method for public display is able to afford engagement and enthusiasm from a particular target audience.*

### 4.1.1. Introduction

Our cities are increasingly permeated by different forms of sensing and monitoring technology, offering new opportunities for overlaying the physical space with a digital world of data. Within the context of smart cities, it has been hypothesized that this digital, real-time lens will allow us to tackle various contemporary urban challenges, such as traffic congestion, scarcity of energy or cultural diversity (Galloway, 2004). These emerging data sources also provide novel opportunities to inform citizens more effectively, such as how their collective activities cause (or may help solve) these urban challenges, with the ultimate goal to nudge their behavior to more sustainable alternatives. Within this context, research efforts on urban visualization aim to make such urban data more accessible and actionable by communicating this data situated within the urban environment itself (Vande Moere and Hill, 2012), in order to encourage citizens to reflect upon their own environment (Koeman, Kalnikait and Rogers, 2015) or actively participate in civic discussions (Koeman, Kalnikait and Rogers, 2015; Taylor, Lindley, Regan, Sweeney, Vlachokyriakos, Grainger and Lingel, 2015). A bicycle count display (e.g. (Eco-compteur, 2015)) forms a particularly intriguing example of urban visualization, as it captures and conveys simple, quantitative information within the situated setting of the city. Moreover, the presence of a bicycle count display acknowledges and reinforces a sense of belonging for a particular (cyclist) community (Forrest and Kearns, 2001). Most interactive, public display installations (e.g. (Steinberger, Foth and Alt, 2014; Valkanova, Walter, Vande Moere and Müller, 2014)) specifically target pedestrians, which however form only a particular subset of a typical urban population. We thus believe that cyclists to date are often overlooked as engaged citizens, as well as potential HCI users. Moreover, as cycling has been increasingly promoted as being instrumental to help solve modern urban mobility issues (Newman and Kenworthy, 2015), this target group is increasing and quickly gaining civic importance.

We therefore investigated a novel interaction design for a bicycle count display that is able to to convey richer forms of information and gather qualitative data from cyclists. Within this challenge, we investigated aspects of usefulness and usability, including the ergonomic efficient and playful facilitation of the input, as well as the insight generating capacities of the output media. As one of the first HCI studies to explore interactive public displays specifically targeting cyclists, our research questions are exploratory in nature:

- RQ1 (input): How can cyclists efficiently participate in public polling?
    - With sub-RQ1a: What is impact of several types of interaction design?
    - And sub-RQ1b: What is the impact of context, such as location?
- RQ2 (output): How can cyclists be informed by an urban visualization?
    - With sub-RQ2a: How to communicate information with public displays to fast-moving users?
    - And sub-RQ2b: How to generate insights on the displayed information?

Figure 4.3 Cyclist confirms personal opinion with a button press, located on a handrail (left); two cyclists, both at location SUB (middle); and the polling question shown on the LED display at location URB (right).

By describing our rationale during the user-centered design process, and evaluating how people engaged with the hi-fidelity prototype in a real world setting, this paper provides insight in how well-specified and limited forms of interaction encourages according community members to civically participate. Specific attention was given to guide cyclists through successive phases of engagement. The design was constrained by realistic demands, such as low-resolution, yet affordable and robust input and output devices.

### 4.1.2. Related work

**Interaction in public environments** Interaction with public displays typically occurs by pedestrians, facilitated via touch screens (Kukka, Kostakos, Ojala, Ylipulli, Suopajärvi, Jurmu and Hosio, 2013), gestures (Valkanova, Walter, Vande Moere and Müller, 2014) or by the use of personal devices such as smartphones (Rukzio, Müller and Hardy, 2009). However, public displays are often faced by 'interaction blindness', i.e. passers-by often do not recognize their interactive capacities (Ojala, Kostakos, Kukka, Heikkinen, Linden, Jurmu, Hosio, Kruger and Zanni, 2012), while smartphone applications rely on less opportunistic and more dedicated ways of considering or commencing engagement. More contextual ways of public interaction have been explored, such as blending elements of the built environment with public polling (e.g. (Koeman, Kalnikait and Rogers, 2015)), deploying a large screen for full-body interaction (Hespanhol, Tomitsch, McArthur, Fredericks, Schroeter and Foth, 2015), adding tangible elements (e.g. (Claes and Vande Moere, 2015)), or placing other curiosity-triggering elements (Houben and Weichel, 2013). For instance, interacting with one's feet by means of an interactive floor (Schieck, Briones and Mottram, 2008) or floor-based buttons (Steinberger, Foth and Alt, 2014) have a low-threshold to engagement, and makes civic participation by pedestrians more effortless, both mentally as physically.

**Cyclist-specific interaction** Most interactive applications targeting cyclists focus on aiding way-finding or creating personal experiences via smartphone applications (e.g. (Rowland, Flintham, Oppermann, Marshall, Chamberlain, Koleva, Benford and Perez, 2009; Pielot, Poppinga, Heuten and Boll, 2012)). Efforts to integrate the physical environment in the interaction experience include a bike-mounted projection that displays navigational information on the ground (Dancu, Franjcic and Fjeld, 2014) or - when cycling in group - a display that is mounted on the back of a bicycle helmet conveying health information to following cyclists (Walmink, Wilde and Mueller, 2014). Integrated displays, such as t-shirts with wearable flexible displays (Mauriello, Gubbels and Froehlich, 2014) and projectors integrated in bicycle seats that display unto clothing (Sheth, 2015) are potentially useful for public information sharing on bicycles.

Another range of cyclist-specific interaction modalities exemplify how the environment can act as the information carrier, such as a bicycle tunnel with an app-based adjustable LED lightning schema (Architecten, 2015), or a display that asks passers-by questions like *"which bird do you hear?"* above the entrance, and displaying the correct answer at the exit (Stallen, 2012). Both tunnel installations aim for cyclists to feel safer and at ease. In turn, *Bicycle Counts* creates a public experience via a public projection that represents each passing cyclist in terms of individual and collective financial savings (Birt, 2012). Dedicated polling systems exist that specifically target cyclists, such as by allowing passers-by to answer a survey question through riding on the appropriate 'yes' or 'no' cycle path (Verkeersnet, 2015).

### 4.1.3. Design

For this study, we collaborated with the civic government of Leuven, a mid-sized city in Belgium, who expressed the goal to invest in a mobile bicycle count display.

**Design Requirements** In spite of not yet having an appropriate way of displaying any form of public feedback, the local government already utilizes numerous bicycle counter devices underneath several local cycle paths. These devices continuously capture data such as the number of passing cyclists, the speed of passing cyclists, the time and date they passed, the type of their bicycles (e.g. child bicycle, adult bicycle or motorized bicycle), precipitation, and outdoor temperature. Due to the richness of the available data, we specifically aimed to design for ways to display more than simple statistical facts to cyclists (e.g. number of cyclists passing by), allowing for deeper forms of insight generation. In addition, we wished to contextualize the available quantitative data by exploring how qualitative opinions could be collected from the cyclists themselves. As the combination of both user input and output/feedback requires several physical and perceptual activities, we chose to target cyclists when they stand still, such as at a traffic light or an intersection. As a final design goal, we aimed to design a system that was playful and fun to use, yet still realistic, safe, affordable and easily deployable at diverse locations, hereby noting the required robust nature of urban infrastructure. Accordingly, we quickly disregarded the notion of higher resolution LCD or LED displays, as well as touch-enabled displays.

The local government proposed additional requirements, i.e. being inexpensive while also being mobile (so that it could be placed at various frequented locations), yet be weather- and vandalism-proof (so that it could be left unsupervised for longer periods of time). Furthermore, the bicycle counter display should be legible for multiple cyclists (and other passers-by) at once, both close-by as from a distance, in order to warrant an accessible and public character.

#### 4.1.3.1. Input: Evaluating interaction alternatives

We introduce *Bicycle Barometer*, which is based on a novel interaction method to vote and operate a public, informative display. The construction and design of the input interaction method followed a three-phased user-centered, iterative design approach consisting of: 1) field observations that inspired two low-fidelity input device mockups; 2) the design and evaluation of low-tech prototypes of three interaction alternatives; and 3) the comparative evaluation of the ideal interaction methods to select the most effective.

Figure 4.4 Footrest: physical buttons (left) versus non-physical buttons (right).


Figure 4.5 Floor mat: horizontal layout (left) versus vertical layout (right).

Figure 4.6 Handrail: large buttons (left) versus small buttons (right).

## Exploratory Interaction Study

In order to assure our system would be perceived as unobtrusive, we conducted an ethnographic pre-study to reveal how cyclists typically behave during waiting situations. During two consecutive hours (i.e. noon, 11am-1pm on a Wednesday), one researcher observed a busy, 4-armed intersection at the edge of the city. Of the 152 observed cyclists, we noticed how 62 (41%) cyclists used the raised curb to rest their feet. Few individuals (5) grabbed a traffic sign attached to the traffic light to lean on while their feet stayed on the pedals, and a single individual balanced his bike during the entire waiting time. This behavior was different for those not positioned at prime, frontal positions, as less or no physical supports like curbs were available further away from the crossing. To allow cyclists to likewise exploit a physical structure to lean on, we inspired our physical design on existing cyclist-specific urban furniture, such as a footrest (e.g. (Copenhagenize.eu, 2014)) or a traffic light handle (e.g. (Grix-Saar, 2015)).

Accordingly, we evaluated a low-fidelity mockup of an interactive footrest and an interactive handrail, constructed out of materials such as wood and foam. Small evaluation studies with 24 volunteering participants captured the influence of the shape, size and height on the balance, comfort and support while people interacted. We noticed how many cyclists liked to keep going back and forth with their bicycle while finding support via the handrail or footrest. As a result, we were inspired to design a third interaction method, which tracks the relative front wheel position of a bicycle on a pressure-sensitive floor mat.

## Low-tech prototypes

For each of the three chosen interaction methods, we integrated an identical feedback method that revealed a clear and immediate confirmation of one's interaction. We built two low-tech prototype alternatives for each of the three interaction methods, and evaluated them individually in a real world setup, i.e. a cycle path on a university campus. 30 volunteering cyclists were recruited per interaction method, and invited on the spot. The feedback was simulated through a Wizard-of-Oz setup: participants selected and confirmed their personal response (i.e. a 5-point agreement scale) for a particular question that was displayed on a common LCD screen, e.g. "*Are there sufficient parking lots for bicycles?"* Afterwards, participants answered a short semi-structured interview, based on four questions of the NASA task load index (Hart and Staveland, 1988) in order to measure the physical load and comfort, for both the polling as the feedback features.

**Footrest.** We compared the user experience of a physical button versus a touch sensitive footrest, both operated with a single foot (Figure 4.4). The use of a footrest for interaction implies that a cyclist needs to support both body and bicycle with a foot at all times. While pressing a physical button with a foot might be less comfortable than touching a platform, a physical button provides some form of direct feedback (e.g. the shifting movement of the button) that does not require any other external feedback for confirmation, like sound, vibration or a visual alert. Most participants did not rate the footrest button as comfortable because they needed to lift their foot to press, causing some instances of instability. The non-physical footrest buttons were also rated as uncomfortable because participants had to switch their gaze from their feet up to the display to notice the visual feedback.

**Handrail.** We preferred to evaluate a horizontally positioned bar support as it is more flexible to temporally place in the environment than a vertical one. The bar was equipped with physical buttons in order to facilitate easily perceivable tangible feedback. The two prototypes compared large, hand-sized buttons versus small, finger-scaled physical buttons (Figure 4.6). Most participants pressed the large buttons with one finger, denying support with the rest of the hand at that time. All the small buttons were in reach of the pointing finger while supporting the rest of the hand at all times, which was also rated as most comfortable.

**Floor Mat.** We designed two floor mat layouts. One floor mat featured a vertical layout, allowing a form of up-and-down 'scrolling' like a window scrollbar (Figure 4.5, left). In turn, a horizontal layout framed each answer in a separate compartment (Figure 4.5, right) that forced cyclists to determine the desired wheel position before entering the mat, or reposition the wheel by first putting both feet on the ground.

Like the footrest, gazing up and down from the mat to the display for feedback was not rated comfortable for both layout alternatives. The horizontal layout provided more certainty about the selection of their response, while selecting and interacting with the vertical layout was considered playful and fun. The maximal, interactive vertical zone of the floor mat is 60cm, as it is not comfortable when a bicycle wheel needs to bridge more space.

### Combined interaction methods

The three most promising interaction alternatives (handrail with small buttons, footrest with non-physical buttons and floor mat with vertical layout) were also evaluated in parallel, all integrated in a single system, 30 coincidental passing cyclists were stopped and asked to participate. After testing one alternative, they were asked to fill in a survey based on 4 questions of the NASA task load index to measure physical load and ergonomics (Hart and Staveland, 1988). After testing all remaining interaction methods, they were invited to give a preference rating in terms of user experience, fun and attractiveness, and were administered a semi-structured interview to further explain their replies.

Figure 4.7 Participant adds a card sticker with a type of data in the workshop.

Overall, the footrest scored lowest in all preference ratings. The handrail was considered most comfortable and provided most reliable feedback. The floor mat was rated as most fun and most attractive in appearance. Furthermore, the floor was considered to specifically accommodate the use of a bicycle, which was mentioned as a potential motivation for use.

#### 4.1.3.2. Output: Co-designing the information display

To include the cyclists' informational needs in the design of the output, we organized a 2-hour co-design workshop with 9 participants (3 female, mean age: 35, SD: 5), consisting of eight cyclists and one local government representative. The workshop structure was based on a mapping method (Huybrechts, Dreessen and Schepers, 2012), which was divided into three successive phases: 1) the kind of information cyclists want to be informed about in the urban environment; 2) types of data that cyclists consider relevant; and 3) types of visualization that are can be used to present the statistical data in comprehensible ways.

The discussions revealed that cyclists did not want to become aware of distinct facts and statistics, but were rather interested in receiving contextual information and stories, specifically targeting their personal situation and potentially connecting this to other meaningful trends. The subsequent co-design of data-driven stories then focused on using common frustrations as starting points for engaging cyclists to answer specific questions in public (Figure 4.7). We deployed the card sorting technique to relate existing frustrations to what is typically captured in existing data sources. Lastly, we used card sorting again to discuss possible visualization techniques that combine the accessible style of infographics (i.e. pictograms, emoticons), with more '*trustworthy*' bar and line graph diagrams (Figure 4.8).

### 4.1.4. Implementation

Based on the insights from our exploratory design studies described above, we developed a working, hi-fidelity prototype. We selected the floor mat (vertical layout) as the main interaction method to browse between possible poll answers. As the floor method did not provide intuitive or efficient ways of confirming one's vote, we decided to keep one button on the handrail as the interaction method for confirming the interaction (e.g. submitting the vote) while also facilitating physical support (see Figure 4.2 for an overview of the prototype set up). Based on

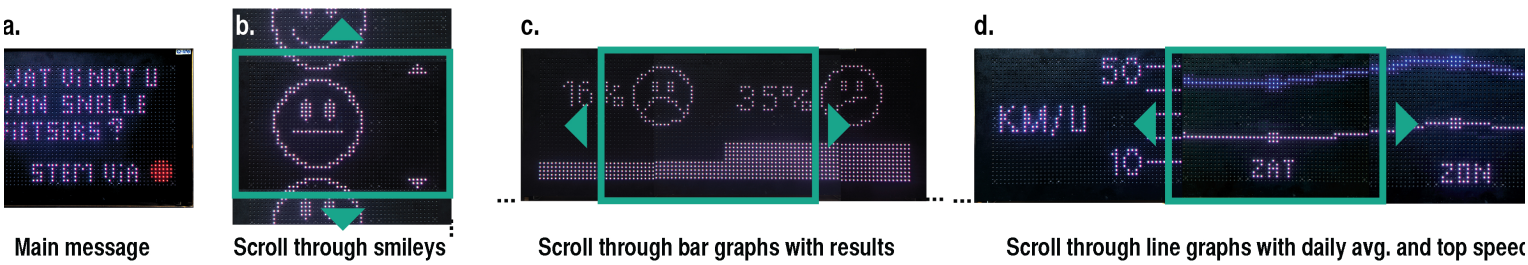


Figure 4.8 Screen shots of the narrative flow on the LED display: main message "*What do you think of fast cyclists? Vote with [red dot]*" (a), selection of smiley faces (b), results as a rolling bar graph (d) and average versus top speed in km/h ("*Km/u*") on Saturday ("*ZAT*") and Sunday ("*ZON*"), presented as a rolling line graph (d).

the input from the workshop, we selected the provocative frustration *"Cyclist-terrorists are a burden"*. Inspired by actual quantitative data from the existing bicycle counters which we thus could visualize, we rephrased it into an open-ended question, i.e. "*What do you think of fast cyclists?".* The system allows passing cyclists to vote by selecting one out of five possible smiley faces, ranging from very unhappy to very happy. After the poll, the system then continues with a data-driven story, which encourages cyclists to browse through past polling results. Finally, the system offers to explore a specific yet relevant data set captured by the bicycle count system, i.e. the top and average speed per day.

Constrained by the already mentioned technical and practical requirements, we chose to integrate a small, low-resolution LED display as output device (resolution of 32x46px, 6mm pixel pitch, and sized 24x38cm). Such small and light display can be easily transported and installed, is reasonably affordable, robust and weather resistant, and can potentially run on solar energy. Next to its excellent contrast even in very bright, outdoor circumstances, a LED display resembles typical urban furniture like common digital traffic signs and does not appear as desirable as a common hi-res LCD display to be potentially stolen or vandalized. However, its extreme low-resolution limited the potential output to minimalistic graphics or four lines of (readable) text. We therefore custom-designed the textual characters, allowing approximately 13 characters per line. Furthermore, as communicating information-dense stories on a low-resolution output is a challenge (Offenhuber and Seitinger, 2014), we custom designed each visualization as one large horizontally stretched graph of which the display only shows a specific, cropped fragment (see Figure 4.8). The cyclist can then horizontally scroll through the graph to understand the full overview.

#### 4.1.4.1. The narrative flow

The display guided the cyclist through a narrative flow, as illustrated in Figure 4.8. It was structured as an interactive slideshow structure, one of the three possible narrative structures of narrative visualization (Segel and Heer, 2010). Accordingly, the sequence of low-resolution visualization fragments could be explored both backwards or forwards by moving one's bicycle wheel respectively towards the back, or the front, of the interactive floor mat. To avoid obvious usability issues, the slides sequence continued in an endless loop. Moving the bicycle wheel to the middle of the mat halted this sequence, and a specific slide could be 'confirmed' or 'selected' by pressing the button on the handrail. More detailed instructions were provided in pictograms right below the display.

To avoid that fast-riding cyclists would not notice the installation in time, we extended the display-driven narrative flow with a physical '*teaser*' in the form of a wooden trestle that announced the installation by the engaging message: "*Cyclist, give your opinion!".* This teaser, located approx. 5 meters in front of the floor mat, thus functioned as a curiosity object (Houben and Weichel, 2013), triggering cyclists to pay attention to the immediate environment. The second stage of the narrative flow consisted of the main displayed question and instructions, i.e. "*vote with [a red circle]"* referring to the red button (Figure 4.8, a). Then, users could scroll through the five possible smiley faces (Figure 4.8, b). After the polling, the overall polling results for each option were represented as one continuous bar chart (i.e. 5 vertical bars arranged horizontally) with percentile values, of which only a fragment is displayed (Figure 4.8, c). Through the scrolling mechanism, visual comparisons between bars were made possible. The top and average speed data were represented as two rolling line graphs (Figure 4.8, d) showing data from over a period of a week, and as such allowed comparisons between two data dimensions and time.

#### 4.1.4.2. Technical and Physical Setup

The higher-fidelity prototype was built with off-the-shelf hardware parts. A *Raspberry Pi* was connected with the LED display via a standard HDMI to DVI input. An industry-grade push button was integrated in the wooden handrail (Figure 4.6, left). The foam floor mat concealed two tracks, i.e. forward (fwd) and backward (bwd), with each track consisting of a series of three pressure sensitive zones in order to evenly distribute the sensors over the width of the floor (i.e. 60cm). On the software side, a set of custom programs was developed in Python to implement the appropriate interaction functionalities (Figure 4.10).

The physical setup was designed to be mobile yet sturdy, but sufficient for shorter-term evaluation study purposes. Obviously, longer-term deployments would require more robust renditions of similar components. A wooden trestle (120cm high) supported the LED display. The wooden construction of the handrail was 80cm long by 110cm high, and the floor mat was 60cm wide by 120cm long.

### 4.1.5. In The Wild Study

*Bicycle Barometer* was deployed during six days, and set up at two different types of locations: an intersection at 1) an urban area (URB); and 2) a suburban area (SUB) (see Figure 4.9). Permission to use the public domain for the in-the-wild study was obtained by the local council beforehand in order to ensure the system would not obstruct traffic or be removed by city cleaning services. At SUB, the *Bicycle Barometer* was deployed from Tuesday to Friday (8am – 6pm). We were not able to record any results on Thursday due to stormy weather conditions, making a total of three days. At URB, the installation was set up during two days, on a Wednesday and Friday (8am – 6pm), in order to capture data during comparable weekdays.

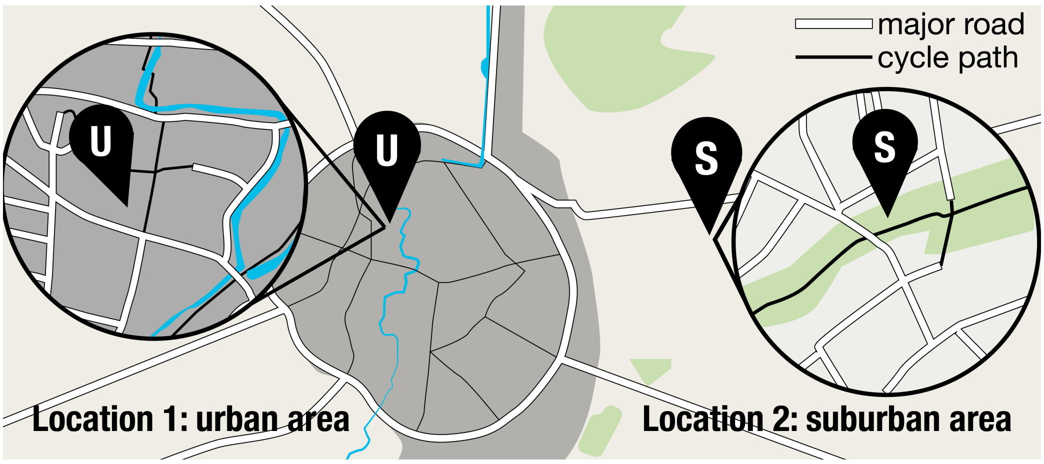


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Figure 4.9 Situating urban (URB) and suburban area (SUB).

evaluation data was collected via a mixed method approach, such as by: i) electronically logging every interaction (i.e. movements with wheel and button presses); ii) a hidden video camera; and iii) observations from one researcher who was present in the vicinity (hidden from sight) at all times. Cyclists were registered as male or female, and their age category was estimated. The behaviors of each passing cyclist were categorized according to the Passive, Active Engagement and Discovery (PACD) model (Memarovic, Langheinrich, Alt, Elhart, Hosio and Rubegni). Passive engagement comprised of glimpsing at the teaser or the display (e.g. turning head towards), or more *immersive forms of interaction* (Memarovic, Langheinrich, Alt, Elhart, Hosio and Rubegni) such as reading while cycling (i.e. keeping one's head turned towards), or riding over the floor mat. Active engagement occurred when cyclists read in a more active way, such as when braking to facilitate reading, or *read 'n interact* (i.e. pressing the button but not confirming). As indicated on Figure 4.12, cyclists in the discovery phase were actively voting, browsed the polling results or explored the statistical data. Furthermore, we also noted at which moment of the narrative flow of the setup (see Figure 4.12), cyclists executed these behaviors.

In total, we interviewed 63 people. 53 semi-structured interviews were held with cyclists who engaged with the installation in some way or form (N=53, 27 Female, Mean age: 45, SD: 17), and 10 with cyclists who did not stop to interact (N=10, 3 Female, Mean age: 53).

After they turned their attention away from the *Bicycle Barometer* installation, we asked participants for demographic information (i.e. age, place of residence); the reasons that triggered them to stop and interact; how they experienced the interaction; and what they remembered of the content they had just explored. The latter question was explicitly formulated in a very broad way in order to encourage participants to report any kind of insight. The reported insights were categorized according to type of data used in the narrative. The insight depth was then scaled according to the insight reporting methodology (Saraiya, North and Duca, 2005). This scale was divided in 3 subcategories of *insight depth*: 1) *factual*, a mere description of data values; 2) *interpretive*, the synthesis of data values with objective knowledge or an existing experience; and 3) *reflective*, which is similar to interpretative, yet contains some subjective, personal or emotional connotations. The electronic logs were analyzed according to the time between events, the number of button presses and when in the narrative flow they occurred.

### 4.1.6. Results & Discussion

Based upon the PACD model (Memarovic, Langheinrich, Alt, Elhart, Hosio and Rubegni, 2012) we grouped the behaviors caused by *Bicycle Barometer* in different forms of engagement (see Figure 4.11) and according phases (see Figure 4.12). As our results show some overlap with previous research on pedestrian-centric public displays, our recommendations will focus on particular aspects that are relevant for cyclist-specific interaction.

#### 4.1.6.1. Passive engagement

Only 13% of the passing cyclists ignored the *Bicycle Barometer* completely (see Figure 4.11). Interviews revealed how several cyclists (16 of 53) were particularly intrigued by the handrail and/or floor, which directed their attention to the display (e.g. *"I wanted to find out what this* [referring to the floor] *was doing here, so I looked at the display").*

The display seemed to be considered as a natural part of the built environment, as cyclists connected its physical manifestation to typical warning signs around schools or hospitals (e.g. "*At first, I thought the display was meant to make us aware of the dangerous situation here, and then I saw the other parts [referring to the handrail and floor]"*). Also the floor was considered unobtrusive, as 19 cyclists (10% of all passers-by) fluently rode over the floor as if it was intrinsic part of the cycle route. Fifteen cyclists of all passers-by riding over the floor glanced to the immediate response shown on the display, and almost half (47%, N=7) returned to the installation (e.g. *"I was surprised it responded when I rode over it, then I saw 'Cyclists' and I wanted to find out what it was about exactly").*

*Design Recommendation:* Past research has shown how interactivity cues like silhouettes (Müller, Walter, Bailly, Nischt and Alt, 2012) or tangible objects (Houben and Weichel, 2013) can effectively lure pedestrians into interacting with a public display. However, as cyclists approach at various yet often faster speeds, more appropriate strategies to attract their attention should be designed. Therefore, a) both the display content and the interactive features offered should become evident in a quick glance. For instance, the use of 'interactive teasers' that react even upon a brief form of interaction (e.g. riding over the floor) seems to be able to sufficiently attract cyclists' attention. b) To alert cyclists who ride too fast or are otherwise distracted to be able to notice the purpose of the installation while riding, the purpose can be gradually announced, such as pictorial or short but readable messages on both teasers as display. Cyclists who become curious yet are still cautious can be potentially convinced by c) allowing low-thresholds to the interaction that do not disturb their cycling activity. Cyclists can also be attracted because of the efficacy of interacting, such by d) optimizing the ergonomic usability so that they are not required to stop or dismount; and by e) designing the physical appearance so that it unmistakably and specifically targets cyclists. As cyclist-specific interfaces are very rare, some of these results might strongly correlate with the novelty effect. However, we believe that specific interfaces targeting clearly distinguishable user groups in the public domain brings powerful advantages, from solving obvious usability issues to calling upon the personal responsibility of belonging to a specific community.


Figure 4.10 To debug the software of the Bicycle Barometer after the first day of the pilot study, the complete set up had to installed.

#### 4.1.6.2. Active engagement

21 of 33 cyclists who initially glanced at the teaser braked, slowed down to read the display and eventually stopped. We grouped these active engagement events in a *situational braking zone* (see Figure 4.12), in analogy with the landing zone for pedestrians (Müller, Walter, Bailly, Nischt and Alt, 2012). Subsequently, these cyclists scanned the environment (e.g. "*In a blink I noticed a wooden trestle that said 'Cyclist,…', and then I noticed this bigger wooden 'thing'* [referring to the handrail] *and a screen with again 'cyclists' on it, which made me believe it was meant for me*"). Half of these cyclists (10) then approached the installation by getting off their bike and walking towards it, or by riding at a very slow speed towards the interactive floor. As all of these cyclists then decided to interact with the installation, we consider this behavior that disturbs the normal cycling flow not as unwanted, as it seems to accommodate those people who are more cautious in nature (e.g. "*I wanted to take a closer look at the installation but then I understood it").* The other half continued riding directly towards the handrail and stopped on the floor. Accordingly, we define an *engagement braking zone* around the physical setup of the handrail, floor and display. Of those cyclists not noticing the teaser but only the display, 51% glanced at the display and slowed down and stopped in the *engagement braking zone* to read the question and vote.

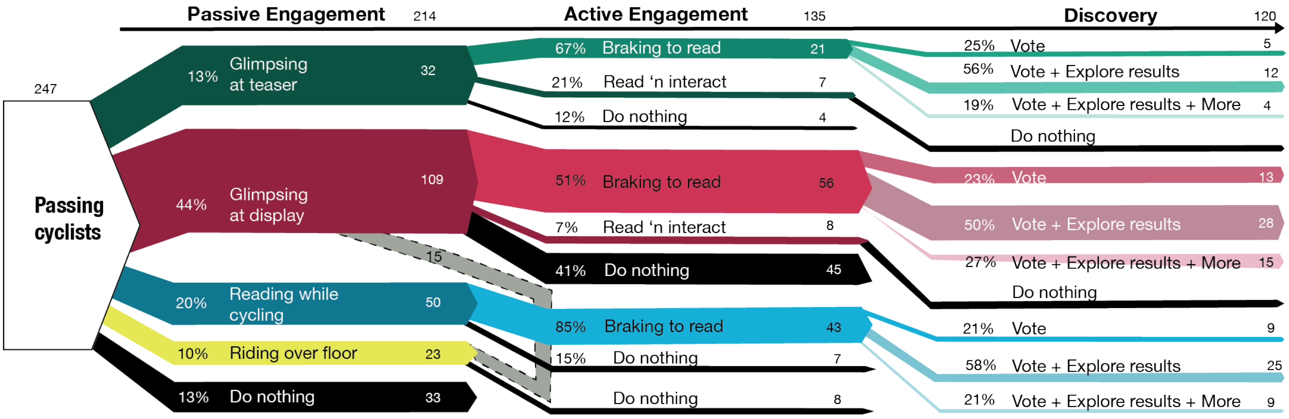


Figure 4.11 Distribution of the number of passing cyclists from passive over active engagement to discovery.

Interviews during the first two hours of the study at URB revealed how cyclists who noticed the teaser did not link its message to the display as they were distracted by the traffic situation. We thus relocated the teaser closer to the display.

*Design Recommendation:* Designers aim to balance teasing potential users and effectively guiding them to the ideal interaction entry point in the pedestrian landing zone (Müller, Walter, Bailly, Nischt and Alt, 2012). For cyclists, this zone needs to be extended as seemingly unwanted effects like halting or dismounting prematurely can actually accommodate personal exploration strategies. Some persons initially require a *situational overview* whereas others have no issue with instantly *engaging* with an interface. In addition, the optimal placement of teasers depends on many contextual factors in the built environment, as teaser and setup should be interpreted as a single, consistent installation. Obstacles that break consistency (e.g. a passage, a garbage can) distract users from commencing or following the narrative flow. These teasers should therefore also be designed to complement the design language of the setup (i.e. use of same materials, color scheme, font, etc.).

### 4.1.6.3. Discovery

Although most cyclists in the active engagement phase (N=97) landed their bike next to the handrail to read, we observed cyclists (N=42, or 31%) who stopped closer to the display, with their rear wheel on the floor, and looking around to find the red button. Yet as all cyclists eventually grabbed the red button after reading the question, its purpose seemed to be clear. 15 cyclists pressed the red button purposefully to go to the second stage but did not select and confirm an opinion. Generally, we noticed most of these cyclists (N=13) to be elderly (age category: 65 y.). We interviewed 2 of them; they mentioned that they did not understand how to navigate further, even after they read instructions (e.g. "*I just did not get it! Aargh, probably I am too old to understand. I just gave up.*"). Although the digital divide might be an obvious reason for such interaction difficulties, many other elderly cyclists (N=34 > 65 y.) did succeed to select and confirm their vote. The other two cyclists that did not vote were teenagers (both 15 y.o.) who were not interested in the question (e.g. "*I wanted to see how it worked but I don't care about that question").*

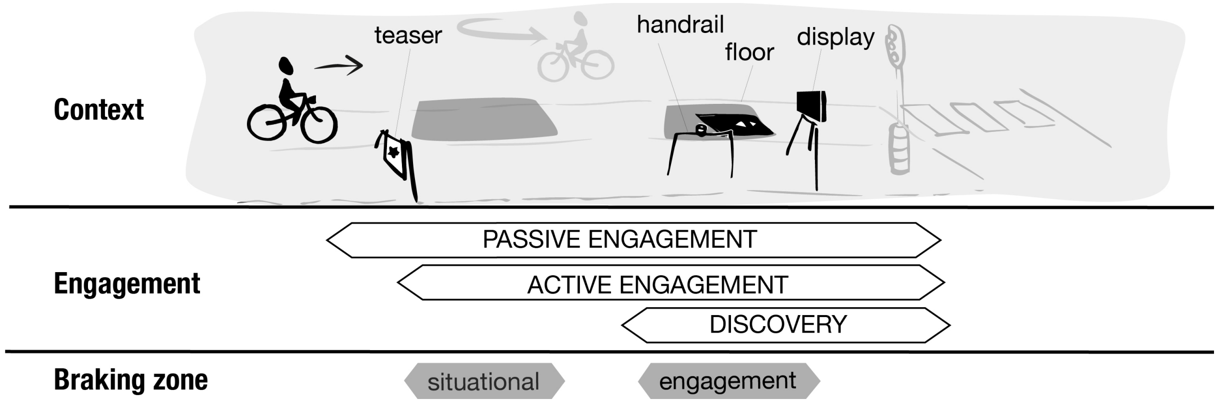

Figure 4.12 Setup of Bicycle Barometer in the context, and the physical distribution of the engagement phases and braking zones.

Design recommendation: As cyclists are seated on, or at least holding onto a bicycle when interacting, they make their participation noticeable, potentially causing social embarrassment (Brignull and Rogers, 2003). We revealed that gradually introducing users to less-familiar interaction methods through the combined use of more familiar methods can be an strategy to overcome this issue. Although Bicycle Barometer had a specific bicycle-wheel interaction design by way of an interactive floor, the first affordance was often discovered via the more familiar physical button. As button presses were immediately followed by an on-screen response, users were confident the system worked, which empowered them to more challenging, less familiar interaction via the floor.

#### 4.1.6.4. Cyclist-specific interaction

While the cyclists were engaged in reading the question and voting, the majority (58%) had both feet on the ground with one foot on each side of the bicycle (see also Figure 4.6, left and middle). Others (37%) stayed seated on their saddle and utilized the handrail support, while the rest (5%) stood next to their bike. The floor mat interaction seemed sufficiently intuitive to select the appropriate opinion. Although most cyclists (112 of 120) used both forward and backward floor motions to navigate around, a few participants (8 of 120) seemed unaware of the backward possibility and only used the forward motion (e.g. *"I missed the one I wanted to vote, so I had to go through all of them again [...], Oh, I didn't see you could go backward as well*").

Interacting via the bicycle wheel was considered exclusive for cyclists (*"I like that you had to do it with a wheel, specific for us - cyclists"),* which made some interviewed participants feel honored (e.g. "*It makes me feel privileged*")*.* Interaction with the wheel was considered fun (e.g. *"It made it feel like a computer game or something"),* and even when combined with the handrail, the interaction was found to be comfortable (e.g. "*comfortable that you can stay on your bike").* Some interviewed cyclists (N= 6) mentioned the specific design as a reason to participate (e.g. *"When I saw it was meant for us – cyclists - I had to try it*"). Despite the cyclist-oriented design, some pedestrians participated, of which we interviewed 5 persons *(*e.g. *"I am annoyed by fast cyclists too").* Although the pedestrians interacted in rather strange looking ways (i.e. dancing on the floor), they did not seem to mind the possible social embarrassment.

*Design Recommendation:* The use of interaction methods that target specific user groups allows for provoking curiosity, lowers the engagement barrier (Schroeter, 2012) and calls upon the sense of belonging to a community (see also design recommendation on passive engagement). Yet, it also seems to encourage subsequent, deeper engagement, such that some people might engage longer because they wish to explore the interaction method for itself. Even if such specific interaction methods might be less intuitive than more established alternatives, its specificity, exclusivity and playfulness helps to overcome apparent usability issues.

#### 4.1.6.5. Encouraging participation

193 votes were registered in total, of which 73 were discarded for this research, e.g. because of too many consecutive button presses. More people voted 'unhappy' (N=35), with a close tie for 'neutral' (N=33). Overall, cyclists appear to be a more engaged audience than pedestrians, at least when the voting rate (i.e. amount of people that voted of all passers-by) of *Bicycle Barometer* (49% or 120 out of 247) is compared to a previous study on public polling displays (24,5%) (Valkanova, Walter, Vande Moere and Müller, 2014). Of those who voted, the majority (74%) also explored the data, at least the stage with the results (see 'Discovery' in Figure 4.12).

Most interviewed cyclists (29 of 53) voted because they cared about the subject matter (e.g. *"I believe fast cyclists are a problem, yes").* As such, they related their opinion to personal experiences (e.g. "*Once I did not see them coming and they scared me so much"),* or the location (e.g. "*Many cyclists just cross the street without stopping. That's so dangerous!").* Others (N=9) indicated to have voted because they were curious what would follow after the question was answered. Some (N=4) mentioned that they expected more explanation (e.g. *"I expected more context to the question"),* clarification on the definitions (N=3, e.g. *"What is meant with fast cyclists exactly? Do I count with my electric bicycle?"*), or the possibility to leave a more detailed reaction (N=1). Six cyclists indicated that a poll with smiley faces was not as nuanced as they desired.

19 cyclists only voted out of idealistic reasons, i.e. they wanted to support the polling initiative to signal the government that they appreciated the perceived interest in cyclists. As such, some of those cyclists (N=15) wanted to support the polling initiative to signal the government that they appreciated the interest in cyclists (e.g. "*It's good that they* [local government] *ask our opinion, so I wanted to take part although I do not have really an opinion"*). Another example of idealistic participation was exemplified by an elderly pedestrian (Male, 74 y.o.), who stopped individual cyclists to convince them to vote: *"it is an important topic as the situation is often dangerous".* Remarkably, he did not vote himself, as he felt *Bicycle Barometer* was only meant for cyclists.

*Design Recommendation:* Similarly to the appeal of urban visualization (Vande Moere and Hill, 2012), public engagement seems not only to depend on the physical qualities of the interaction design but also on the relevancy of the content within a specific, situated context. Therefore, the main displayed message should be carefully formulated as a motivational point for interaction and reflection. One strategy is to include controversial topics (Koeman, Kalnikait and Rogers, 2015) that are relevant yet provocative to the target user group. We also propose to use an open formulation, as this entices people to interact in order to unravel the true purpose or context of the question. This way, participants appropriate the question to their own experience, or feel sufficiently motivated to send a signal to those asking the question. However, including ambiguity might also turn polling results less representative, as voters might interpret the meaning differently.

#### 4.1.6.6. Location depending contextual differences

More passing cyclists voted in the suburban area (SUB, 54%) than in the urban area (URB, 37%), although a similar amount of passing cyclists did nothing (13% SUB versus 15% URB). There may be several explanations for this behavior. For instance, the question might be perceived as more relevant or pertinent in SUB as it was located at a known dangerous intersection (e.g. *"I was not interested in the question displayed, so I did not respond. I wanted to give my opinion on the quality of the cycling paths, though").* There might also exist a difference in the time that a cyclist has available: SUB cyclists generally plan longer trajectories and thus have less strict time constraints. Lastly, urban environments might be more distracting, and its occupants might be more inclined to ignore unknown visual stimuli.

*Design Recommendation:* The participation rate is impacted by objective parameters such as the built environment (i.e. suburb or urban), and more subjective parameters such as the contextual meaning of a location (Schieck, Briones and Mottram, 2008) (e.g. a dangerous intersection), or the relative time availability of the passers-by (e.g. SUB participants have more time). We therefore propose choosing locations in relation to longer trajectories, such as for commuting or recreation. Designers could also become familiar with the situated context through informal conversations with local inhabitants or authorities, and potentially exploit the discovered subjective meanings.


Figure 4.13 *Bicycle Barometer* in urban area URB (left) and in the suburban area SUB (right).

### 4.1.6.7. Exploring the urban visualization

Most cyclists who voted (93 of 120) also explored the subsequent visualization of the results. They seemed especially interested in discovering where 'their vote' was situated, as almost half (N=23) of the 53 interviewed participants were able to remember the percentile number of the most popular vote, and the percentile number of their choice. Participants reported making comparisons between the polling results, during which they made broad generalizations instead of recalling exact numerical values (e.g. "more people voted unhappy than neutral").

The subsequent option to explore the general data in the form of rolling line graphs seemed less popular. Although this feature was announced on the display (i.e. when the results were displayed) and on the instructions, people seemed eager to continue their trip and did not seem to notice the graphical option to commence exploring – (e.g. "Oh, after I found out how other people voted I just left, I did not know there was more […] But I wanted to move along anyway"). Some cyclists (N=3) also explained that they disliked the way the data was represented because it was too difficult (e.g. "It was something with a graph, but I do not understand that").

Cyclists who explored the line graph visualization (28 in total, but interviewed N=13) were able to extract insights, and interpreted them according to their personal opinion (e.g. "On Sunday, we cycle much faster in general, I would expect the opposite.") or situation (e.g. "Wow! Top speed on Sunday was 50 km per hour? I can only get that when I cycle down from a hill"). These insights also encouraged cyclists to nuance their opinions (e.g. an amateur road bike cyclist said "When I see it in numbers, we cycle much, much faster than the average cyclist, more than double! However, I think there is space for both of us").

Design Recommendation: In public space, physically situating a display at a specific, context-rich location, e.g. positioning it on or nearby a bicycle path, forms a particular approach to nudge passers-by into personal sense-making (Vande Moere and Hill, 2012). Moreover, we also demonstrated how the specificity of the interaction design itself, e.g. accommodating people to manipulate their bicycles without needing to get off or stand down, further contributes to this sense-making process. In addition, our results show that most people were encouraged to interact further after leaving their vote. As some people were interested in knowing the overall polling results, while others wanted to discover more detailed information, it is advisable to design a particular interaction flow that 1) provides some gratification in terms of informing participants; and 2) allows for different information consumption behaviors; from browsing bite-sized facts to allowing more sophisticated analysis.

### 4.1.6.8. Social cyclist-specific interaction

Honeypot effects occurred in 18 occasions, although it was not obvious in terms of waiting behavior. We noticed two types of grouping attitudes: 1) in 12 occasions, one or more cyclists waited next to the floor mat (as illustrated in Figure 4.3, middle) on which the interacting cycling was standing; 2) in six occasions, cyclists formed a neat queue behind the interacting cyclist. During one of those occasions, a recreational cycling group of 13 people arrived, to whom the purpose of the installation was passed down verbally, This prompted five cyclists to wait in line in order to participate, while the other eight were grouped around them to wait and gaze at the display. We also observed that when cyclists stand next or behind each other, they needed to

Figure 4.14 Multi-user interaction at location SUB.

talk loudly to bridge the distance between them, which might be influenced by the physical dimensions of the bicycles. However, the physical dispersion of cyclists probably influenced their willingness to start a conversation. Groups discussed their opinion with each other (e.g. “The problem is the speed of the cars” – “I don’t agree with you on that”) or were imagining solutions (e.g. “They should install a bridge for us, than there is no problem”). Furthermore, multi-user bicycle use afforded collaborative efforts. For instance, we observed cyclists with young children (e.g. on a child seat, in a cargo bike) who interacted together, i.e. an adult navigated via the floor while the child pressed the button (Figure 4.14).

Design Recommendation: When designing for a social interaction space around a public display (Fischer and Hornecker, 2012), bicycles occupy more space than pedestrians. As a result, both the physical dimensions of the interaction space and the potential waiting line occupy a larger space than with more traditional public displays, potentially causing traffic obstructions. These physical constraints also limited spontaneous social interaction. Future work could explore collaborative possibilities of cyclist-specific interaction.

### 4.1.7. Limitations

Overall, identifying appropriate locations and receiving the permissions to undertake in the wild research in traffic-sensitive situations is a cumbersome undertaking, as it involves the joint agreement of many different authorities. Upholding security is of utmost importance, as any intervention in traffic potentially interferes with the personal wellbeing of participants. Therefore, as the performance of a public installation like Bicycle Barometer is influenced by the contextual situation existing in its immediate vicinity, benchmarking different interventions, comparing otherwise controlled conditions, or even reproducing results is potentially challenging. Moreover, even environmental factors like the physical availability of space, the type of neighborhood or the time of day need to be taken into account. Therefore, the reported percentages provide only general indications, in spite of the considerable large number of in-the-wild study participants.

The choice of display technology may influence the results in terms of output qualities. For instance, our low-resolution LED display output was limited to basic visual mappings, which required additional interaction modalities (i.e. scrolling). Similarly, a high-resolution display may present more data in a glance.

#### 4.1.8. Future work: civically involved cyclists

Our results open up new opportunities to facilitate cyclists to become publically involved citizens who are better informed and able to participate in relevant civic debates. Involving the cyclist community in the generation of statements and questions causes more accessible and relevant debates (Koeman, Kalnikait and Rogers, 2015), and cyclist-specific questions could be generated by bottom-up public participation projects as (Le Dantec, Watkins, Clark and Mynatt, 2015). Alternatively, questions that are generated from a top-down perspective allow local governments to retrieve qualitative opinions in relation to the quantitative data they already capture, facilitating more informed forms of policy making. For instance, installations like the Bicycle Barometer could gather hyperlocal sentiments about potential planning alternatives, or clarify patterns within bicycle count data.

#### 4.1.9. Conclusion

This study demonstrated the potential qualities of a cyclist-specific polling interface. More importantly, the participation rate in addition to the participant comments demonstrates the apparent societal demand for these kinds of public, interactive interfaces. We have shown how designing an interaction modality targeting a specific user group is able to overcome usability issues and instead generate sufficient engagement to participate. In addition, our public polling approach has demonstrated that when people are encouraged to vote, they also are sufficiently motivated to explore the relevant results and dive into insight-generating processes. As such, our research forms the evidence towards how new forms of interaction can target specific user groups to become involved citizens.

## 4.2. The role of material dimensions on engagement with Bicycle Barometer

This chapter has been published as:

Claes, Sandy, and Andrew Vande Moere. "Replicating an In-The-Wild Study One Year Later: Comparing Prototypes with Different Material Dimensions." Proceedings of the 2017 Conference on Designing Interactive Systems. (pp. 1321-1325) ACM. DOI: 10.1145/3064663.3064725
Acceptance rate: 22%

Presented at DIS'17 conference on June 14, 2017 in Edinburgh, United Kingdom.

### My role

*The results of the previous study convinced Q-lite, a public signage company to further develop Bicycle Barometer for long-term deployments. The province of Vlaams Brabant was interested to further deploy Bicycle Barometer in the context of a project on cycle highways, to evaluate cyclists' perceptions on this phenomenon and display data on speed.*

*The resulting publication was authored primarily by myself, with support from Andrew Vande Moere.*

Figure 4.15 Colleague Eslam Nofal tries the progressed version of the prototype.


*Figure 4.17 Bicycle Barometer at the suburban deployment area (Kessel-Lo, Leuven).*

## Abstract

*The in-the-wild methodology involves the evaluation of a functioning prototype in an everyday context, during which the participants are typically left unaware of the actual study context. As the material dimensions of such a prototype imply a preliminary status, the apparent difference between prototype and the final end product might affect the actual ecological validity of the evaluation results. By replicating an in-the-wild study of an identical yet progressed high fidelity prototype versus its research product one year apart, we aim to investigate the impact of material dimensions on user behavior. Our results demonstrate how impermanent material dimensions tend to increase the participation rate and augments reflection on ownership; imperfect dimensions reduce the expectations and contextual appropriation of an installation; and incomplete dimensions imply a relationship with the investigator. We thus claim that material dimensions affect the evaluation outcomes of in-the-wild evaluation studies.*

### 4.2.1. Introduction

The in-the-wild study methodology (Rogers, Connelly, Tedesco, Hazlewood, Kurtz, Hall, Hursey and Toscos, 2007) forms an ecologically valid approach to understand how humans relate to technology in everyday contexts, which include urban (e.g. (Taylor, Marshall, Blum-Ross, Mills, Rogers, Egglestone, Frohlich, Wright and Olivier, 2012)), sports (e.g. (Mueller and Muirhead, 2015)), and domestic (e.g. (Brush, Lee, Mahajan, Agarwal, Saroiu and Dixon, 2011)) environments. Often, these studies involve the deployment of a high fidelity (hi-fi) prototype (Chamberlain, Crabtree, Rodden, Jones and Rogers, 2012), which is a placeholder for *something else*, an instantiation of what the designer expects *it might become* (Lim, Stolterman and Tenenberg, 2008). In-the-wild studies that are performed in public space, typically deal with participants that are not informed that they are engaging with a hi-fi prototype, although its material dimensions, i.e. *role, look and feel, implementation* (Houde and Hill, 1997), often implies a preliminary design status. As this status might lead to participants not perceiving a prototype for its present state but for its future, envisioned potential (Schon and DeSanctis, 1986; Wakkary and Maestri, 2007), the representativeness of its in-the-wild evaluation might be affected. A design that looks unfinished, for instance, triggers different types of user adoption and long-term interaction behaviors than finished-looking ones (Tsaknaki and Fernaeus, 2016). Recently, the notion of *research product* was proposed to overcome some of these complex and situated limitations of a prototype (Odom, Wakkary, Lim, Desjardins, Hengeveld and Banks, 2016), as a research product maintains a clear design research focus, while allowing participants to experience the material dimensions *as is* rather than *what it might become*.

In this paper, we contrast the results of an identical in-the-wild study of two renditions of a public installation that only differ by their look and feel, and thus form representative samples of a prototype and its progressed research product (Odom, Wakkary, Lim, Desjardins, Hengeveld and Banks, 2016). We discuss how the material dimensions impact user engagement through the Wabi-Sabi lens (Tsaknaki and Fernaeus, 2016). Our study also contributes as a replication study, aiming to contrast and reflect upon originally acquired knowledge (Hornbæk, Sander, Bargas-Avila and Grue Simonsen, 2014), and presenting an empirically supported expansion of recent theoretical considerations on the material dimensions of prototyping (Odom, Wakkary, Lim, Desjardins, Hengeveld and Banks, 2016; Tsaknaki and Fernaeus, 2016).


Figure 4.17 A cyclist interacts with the prototype (left), the prototype installation in wood (middle left) versus the research product as installation (middle right) and in use by a cyclis (right).

### 4.2.2. Material dimensions

In this paper we base our definition of material dimensions on (Houde and Hill, 1997), in which the *role* refers to the function the prototype plays in a users' life, *look and feel* deals with the sensory experience and *implementation* refers to the actual components that facilitate its functioning.

*Role:* The subject of our study is a public voting installation that was custom-developed in the context of a civic awareness campaign on bicycle usage (Claes, Slegers and Vande Moere, 2016). More specifically, the installation was deliberately designed to only target cyclists, hereby excluding contributions of pedestrians. Due to the positive and promising results of the initial in-the-wild study of the high-fidelity prototype (Claes, Slegers and Vande Moere, 2016) the local government requested to pursue our study, and design and supervise the physical construction of the installation for unsupervised and long-term deployments.

*Implementation:* The interaction flow, modalities and hardware were left unaltered. Each installation contains a teaser board inviting passers-by to vote. Instructions as well as a short text that links the installation to the local government are provided below the LED display. The LED display shows a provocative question (i.e. *"What is your opinion on speeding cyclists?"),* after which the voting procedure comprises of selecting an appropriate smiley face by navigating the front bicycle wheel forwards or backwards on a weight-sensitive floor mat, and confirming the vote by clicking on a button that is integrated in the armrest. Then, the display conveys the cumulative results of the historical votes by way of percentile number and a bar chart that can be similarly scrolled via the floor mat. Finally, the display offers topical data about average and top speed represented as a sequenced line graph, which can also be explored via the floor mat. It should be noted that while research product offered more technical features, including a higher number of possible screen characters and automatic updates, these were disabled during the study in order to maintain comparable conditions.

Table 4-1 Comparison of evaluation times

| | Prototype | Research Product |
|---|---|---|
| **Period** | Aug- Sep 2015 | Aug-Sep 2016 |
| **In city centre** | Fri, Mo | Fri, Mo |
| **In suburbs** | Tue, Thu, Fri | Tue, Thu, Fri |
| **Deployment time** | 8am-6pm | 8am-6pm |
| **Researcher present** | 30 hours (of 50) | 30 hours (of 50) |

*Look and feel:* The fidelity of both conditions mainly differs in terms of their look and feel, which we categorize according to the three themes of Wabi-Sabi (Tsaknaki and Fernaeus, 2016). First, our initial prototype appears to be *incomplete*, as we deliberately wanted to modify, add or move attributes of the installation during the iterative design process. Indeed, each interaction modality of the prototype was designed as a modular entity, to allow us to make small changes to the LED display setup, floor mat or armrest when required. It was only during the design phase of the research product that these characteristics were defined and fixed, in order to properly encapsulate the different parts into a single, robust physical structure. Second, the prototype appears rather *imperfect,* as the exposed nails and overlapping wooden slats highlight the uneven handcrafted qualities of the improvised design. In contrast, the material design of the research product aims to be seamless and visual consistent: the thick aluminum tubes remind of common urban infrastructure, such as fences and traffic sign poles. The main aluminum construction is powder-coated in a white color, while several supporting tubes are more hidden in dark grey. These colors complement the blue highlights of the two instruction panels, which correspond to the graphical style of the previously mentioned civic awareness campaign. Lastly, the untreated plywood material, the vulnerable structural setup and a visual appearance that looks out of its place in a public environment insinuate a temporary, *impermanent* character. As the prototype had to be removed every evening for security reasons, its structure had to be easy dismantled and transported. As a result, the parts that hold the LED display and the armrest are foldable. The research product requires an uninterrupted, longer-term set up. Here, the different parts slot into each other in a single, rather large and robust installation (2x1.2x1.6m) that cannot be easily stolen or damaged.

### 4.2.3. Replicating the in-the-wild study

The in-the-wild study of the research product was designed to resemble the prototype study as close as possible. As such, both studies were deployed at the same locations, which are a bicycle lane intersection in the centre and in the suburb of Leuven, a mid-sized city in Belgium. As shown in Table 1, we conducted the study during an identical time period, which is characterized by the end of summer and the beginning of the school year, which brings about a shift in types of cyclists (e.g. recreational versus school children and commuters). Based on local cycling statistics, the cycle behavior varies over a week, requiring the replication study to take place on identical weekdays (see Table 4-1). During the initial study there was a heavy rainfall on Wednesday that prevented the prototype to be set up. Therefore this day is not included in both studies.

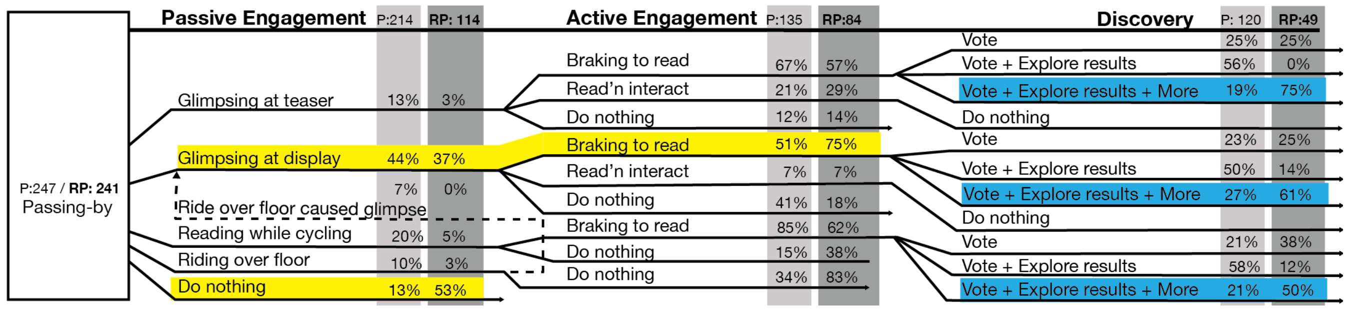


Figure 4.18 Flow diagram that compares the overall results of the in-the-wild study in both urban and suburban setting with the prototype (P, left percentages) versus the research product (RP, percentages on right).

Both studies adopted a mixed method approach. A researcher was present to observe user behavior in a concealed way (i.e. in a car or acting as a casual pedestrian) and record post-interaction interviews. Each interview was taken after a passer-by turned her attention away from the installation. Each interview contained identical questions, concerning what triggered them to stop and engage; how they experienced the engagement flow; what they remembered of the content they had just explored; and some basic demographic information.

Both studies also collected observational data via a concealed video camera, which, in combination with electronically logged interactions, allowed us to analyze and categorize each user engagement stage according to the Passive, Active Engagement and Discovery (PACD) model (Memarovic, Langheinrich, Alt, Elhart, Hosio and Rubegni). In the context of this study, passive engagement comprised of glimpsing at the teaser or the display (e.g. turning head towards), reading the display while cycling (i.e. keeping one's head turned towards), or riding over the floor mat. Active engagement occurred when cyclists braked to facilitate reading, and read 'n interact by pressing the button, but not confirming the action. The discovery phase included at least a voting action, potentially followed by exploring the charts with the voting results or the additional data (see also Figure 4.2).

### 4.2.4. Results and discussion

A total of 63 passers-by were interviewed for the prototype study, and 43 for the research product, a difference that is mainly due to the participation rates during the same deployment time. While the original prototype study triggered a relatively high participation rate (49%), the research product never performed at a similar level (20%). Yet, in comparison to public display engagement in general (Brignull and Rogers, 2003), the participation rate of the research product study is still relatively high. The cyclist-specific role of both p products is obvious, as 30% of the participants (N=19, of 63) in the prototype, and 39% (N=17, of 43) of the research product mentioned how specific design features that target cyclists convinced them to approach the installation, e.g. P14: "*I like how it is meant for cyclists only*".

Figure 4.19 Moving the Bicycle Barometer to the suburban deployment area.

While these results suggest that material dimensions impact participation rate, we wish to point out that the unpredictable ecological conditions of the in-the-wild studies might also motivate the lower participation rate: 1) differing weather conditions such as more sun and hot temperatures, e.g. P6: *“I could not see it (referring to the installation) because of the direct sunlight”* as well as 4 hours more heavy rain falls; 2) local events, such as less days of school but more days of vacation with local events; and 3) less passage of groups of recreational cyclists in the research product study.

### 4.2.5. Impermanence

The impermanent look of a prototype influences how many users will participate on short term, and how critical they will be towards its purpose and presence in the environment.

*Appropriation:* Impermanent material dimensions affect the degree of environmental appropriation. For instance, a bicycle was chained to the research product during five hours, which obstructed the passage to the floor mat, thereby preventing cyclists to interact. Such behavior did not occur in the prototype study. Here, the adoption of the research product by the urban environment led to other, less desirable types of long-term user engagements. Likewise, only cyclists and pedestrians tried the prototype installation, while other vehicle types rode unto the research product, such as motorized wheelchairs or scooters. Moreover, children (N=15) kicked the teaser boards of the research product, jumped on the floor mat, or used the armrest as an improvised playground instrument.

*Ownership:* Impermanent material dimensions impact the perception of ownership. In the prototype study, 17% of the participants (N=11) reported they were initially unsure about the ownership of the installation, e.g. P56 *"I thought it was something the neighborhood committee had put here, but it [referring to the instructions below the LED display] says it's an initiative of the government*", or P53 *"I don't know who put this here, did you [referring to researcher] do it?"*. In contrast, in the research product study, 91% of the participants (N=39, of 43) expected it to be property of an official civic organization, while the others thought the installation was part of a commercial campaign. As such, permanent and complete material dimensions seem to indicate a top-down initiative.

Passers-by were also more critical towards the presence of the research product. In six occasions its mere necessity was questioned e.g. P 37 *"I wonder if my taxes paid for this?*", while such situations did not occur during the prototype study. Both during the prototype and research product study, participants were aware the collected data was owned by the local government, yet five participants of the research product study were also concerned about the impact of this ownership, e.g. P30 *"Why do they [referring to local government] need this data?"* or P26 "*Who is really going to use this information?",* a behavior not observed in the prototype study. As such, the ownership that is implied by the permanent material dimensions may encourage deeper reflection on the actual purpose of the installation.

*Participation urgency:* Impermanent material dimensions impact the users' sense of urgency to participate. Indeed, 30% of the interviewees (N=13, of 43) in the research product study mentioned how time considerations influenced their decision to engage with the installation, e.g. P38: *"I noticed it this morning but I did not have time then. I thought to check it later".* Also the curiosity towards the more ambiguous features of the prototype, including its precise functioning and ownership, affects the immediacy of engagement: in the prototype study, 25% (N=16, of 63) of the interviewees reported they stopped because they *"[…] wanted to find out what it does"* and were unaware they would need to cast a vote*,* while in the research product study, 74% of the interviewees (N=32, of 43) reported they stopped in order to cast their vote.

### 4.2.6. Imperfection

The imperfect look of a prototype affects the expectations and reflections of a participant towards the evaluation target, as it focuses attention to functional shortcomings instead of the more complex relationships with technology.

*Expectations:* User engagement with imperfect material dimensions tends to be less critical and more explorative. In total, the research prototype encouraged 77% of the participants that casted a vote to explore all the available data on the display, versus 15% in the prototype study (percentages are presented in detail per engagement stage on Figure 4.18, in blue), which may indicate participants were determined to explore each available feature of the research product. In addition, six participants in the research product study mentioned they were surprised the


Figure 4.20 Cyclist interacting with Bicycle Barometer in the urban deployment area.

content was rather limited and anticipated the installation would show more questions, like a questionnaire, e.g. P23 *"multiple questions are more representative to my opinion"*, reservations that were not made in the prototype study. Figure 4.18 also shows how the engagement types in the prototype study are more dispersed, indicating more experimental and explorative behaviors; and how the research product attracts less but more determined, active users (see yellow highlights).

*Reflection:* Imperfect material dimensions shift the critical thought of participants towards higher-level goals, such as civic engagement. During the prototype study, 46% (N=29, of 63) of the interviewees commenced to unravel their experience by mentioning an interaction feature, e.g. *"using the wheel was fun"* or "*pushing the button takes too much effort*". For the research product, 86% of the participants (N=37, of 43) immediately reflected about the meaning of the presence of the installation, e.g. positively: *"Finally, the city is giving attention to cyclists!"* (P41), or negatively: *"Is this how the city thinks they can resolve problems of cyclists? They should be here!"* (P2).

### 4.2.7. Incompleteness

The incomplete look of a prototype suggests a personal relationship between the researcher who is present and the prototype itself. Further, researchers should be aware that every design iteration introduces new usability challenges. Usability testing is therefore still needed during every stage of the design (Rudd, Stern and Isensee, 1996), even when evaluating a further progressed prototype (or research product) in-the-wild.

*Design iterations:* Incomplete material dimensions blur the effects of particular usability issues, even making them less apparent. For instance, we encountered 9 occasions during which a passer-by purposefully rode up to the installation and touched the display, e.g. P3 *"I thought it was a touch screen",* a behavior that was only observed twice in the prototype study. This behavior is probably due to the unintended affordances of the new research product display, which features a relatively slick surrounding black aluminum frame and a higher display resolution, which reminds of a touch screen. Notably, the two observations in the prototype study may have predicted this behavior.

*Social reliability bias:* Incomplete material dimensions impact the users' perception on the emotional investment of the researcher in the success of the subject of study, which may prompt them to be more kind about it (Johnson, Rogers, Linden and Bianchi-Berthouze, 2012). In the prototype study, 27% (N=17, of 63) participants asked in some way if the researcher would update the rendition of the installation in the following weeks or months, indicating expectations of being impermanent yet also assuming a direct link with the researcher. In the research product study, the relation of the researcher with the installation was explicitly questioned in five occasions (e.g. P14 "*Are you responsible for putting this here?"*). Naturally, the implied personal link alters the social reliability of the answers, e.g. P31: *"I don't think we need this kind of thing! (silence) But did you design this? I love how it looks though!",* which consequently also affects the study results.

### 4.2.8. Conclusion

The material dimensions of prototypes can offer different kinds of engagement. A prototype with an impermanent and imperfect look cared for more urgent participation and more explorative behavior, while a research product triggered reflections on higher level, e.g. regarding the purpose and impact. This study also shows how incomplete, imperfect and impermanent material dimensions can be beneficial for design interventions, depending on the research questions. We believe our results will help inform the design of public installations that not only will be situated *in* real-world settings but also will be better adopted *by* the real-world.

# 5. Case study IV: Narrative Visualization

In this chapter, we study how narrative visualization approaches can augment engagement and insight generation of public visualization, which responds to RQ1.

This study is published as

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Acceptance rate: 22%

Presented at DIS’17 conference on June 13, 2017 in Edinburgh, United Kingdom.

## My role

*I contacted the public library 'Tweebronnen' in the city of Leuven to ask if they were interested to host a public visualization on bicycle data. The library coordinator invited me to discuss this opportunity, which was concluded with a walk through the library in search for an ideal deployment area.*

*We chose an area outside the actual library but inside the public building. This area is open for a longer time than the library, and serves as a passage between a shopping street, a café and another street. Because of the risk on theft or vandalism of the touch screen and stand, I installed and removed it every day. The very heavy construction was almost impossible to set up by one person, which caused me to ask help of random passers-by.*

*The publication was authored primarily by myself, with support from Andrew Vande Moere.*


*Figure 5.2 Condition non-narrative in the hallway area of the public library.*

## Abstract

*Public displays are increasingly deployed to make civic data easily and publicly consumable. While augmenting such public visualizations with a narrative design strategy could be promising to engage a lay audience, they might perform differently on public displays than on common online media because of the more context-sensitive environment. We therefore report on a comparative in-the-wild study of a public display that contrasts an identical public visualization with and without a narrative structure, and unravel how this affects the user engagement and insight creation process. Our findings indicate how a narrative strategy in relation to contextual aspects supports deeper, more personal reflection on data, connects authorship to the surrounding environment, and overcomes comprehension issues. We believe these results are useful for making public visualizations more effective, as well as understanding why and how lay users interact with and learn from narrative data visualization in general.*

## 5.1. Introduction

Interactive public displays are increasingly deployed to communicate data-in-context (Willett, Jansen and Dragicevic, 2017), for example to inform citizens of local phenomena (Taylor, Lindley, Regan, Sweeney, Vlachokyriakos, Grainger and Lingel, 2015), or to involve them in civic debate (Hespanhol, Tomitsch, McArthur, Fredericks, Schroeter and Foth, 2015; Koeman, Kalnikait and Rogers, 2015). Such public visualizations tend to differ from common (mainly online) forms of data representation in terms of their implicit situatedness (Vande Moere and Hill, 2012), a specific quality that allows the meaning of data to be derived via the implied relationship to the local context, such as the immediate physical and social environment, the perceived ownership of the communication medium, or the relevance and timeliness of the information shown (Vande Moere and Wouters, 2012).

As the societal discussions around many contemporary issues are becoming increasingly grounded by complex forms of data-driven science, there exists a need to understand how non-specialist audiences can be engaged with interactive data representations that allow unbiased yet personal forms of insight creation (Boy, Detienne and Fekete, 2015). Because the impact of such kinds of information visualization cannot longer be solely described in terms of their analytical task performance, it has become relevant to articulate how their design encourages or inhibits the experience of lay people. Yet relative little is known about how public visualization consumption differs from more traditional forms of data representation, and more particularly, whether and how the public and opportunistic context of a physical environment might affect a viewer's insight creation process (Willett, Jansen and Dragicevic, 2017).

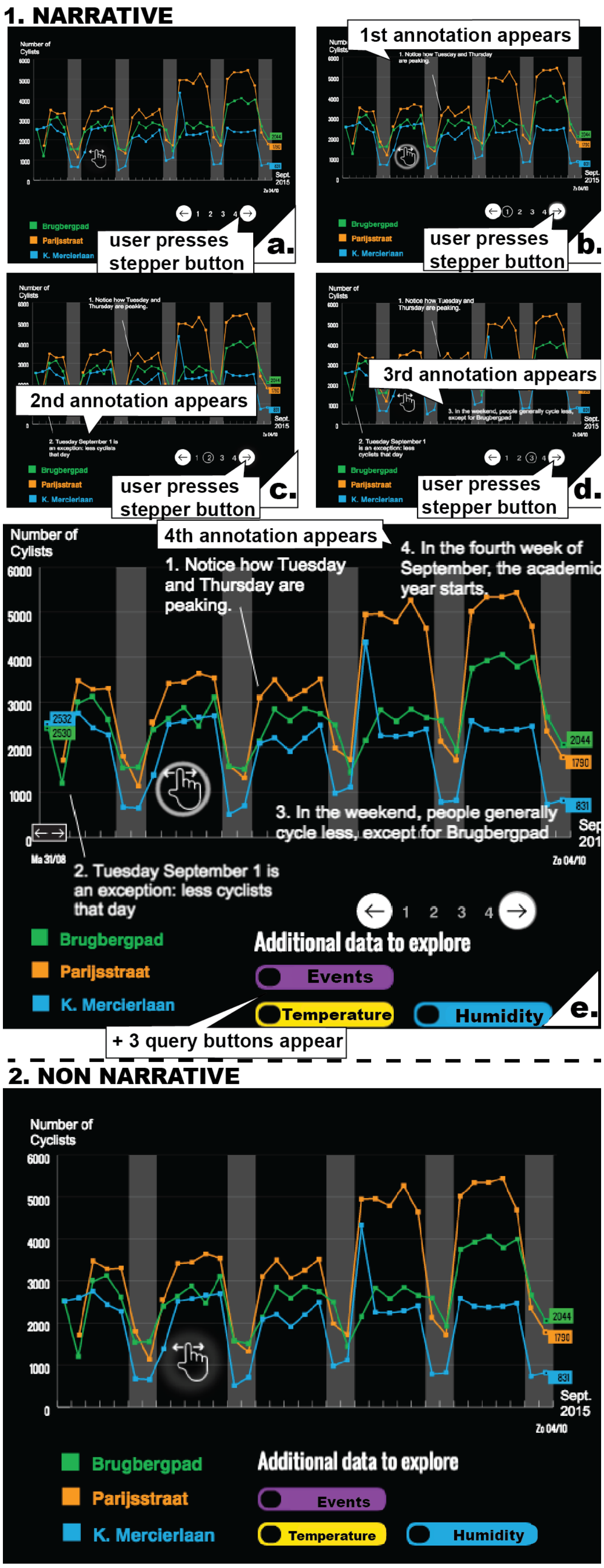



Figure 5.2 Translated version of the interface, note the font is made larger for legibility. The green, orange and blue text in the left corner are names of cycle paths. By touching the charts, exact data for that day is displayed (here: last day of September). In 1) narrative condition (above), sequential steps (a, b, c, d) reveal annotations and guide the user towards open exploration possibilities in e. 2) Without stepper buttons and annotations, interface in non-narrative condition (below) is identical to 1e.

Augmenting visualizations through narrative design strategies forms one approach to appeal (Hullman and Diakopoulos, 2011) and engage a broad audience with data (Amini, Riche, Lee, Hurter and Irani, 2015). For instance, narrative visualization has the ability to partly shift authorship from author to viewer, in order to encourage viewers to gradually immerse themselves in the sense-making process and reflect upon the themes that are embodied by the data (Segel and Heer, 2010). While a recent empirical study demonstrated how the presence of a narrative design strategy did not result in different engagement patterns in an online web setting (Boy, Detienne and Fekete, 2015), we believe that the results differ in a (semi-)public environment, as users tend to interpret information shown on public displays based on the implied context (Vande Moere and Wouters, 2012). Furthermore, we hypothesize that a narrative visualization strategy motivates viewers to gain more personal or deeper forms of insights that reach well beyond those presented in the original narrative. We therefore propose that our research complements the current discourse on narrative visualization, as the qualitative aspect of an insight is difficult to collect in an online study (like [3]), while opportunistic or casual use characteristics are hard to simulate in a laboratory study setting. In contrast, an in-the-wild study (Rogers, 2011) offers the opportunity to gain additional qualitative feedback by interviewing actual users and even those people that chose not to interact, while also allowing a broader, and potentially less technology-savvy user audience to be captured.

## 5.2. Case study

In order to benchmark the influence of the presence of narrative design strategies on the different stages of user engagement, we conducted a comparative in-the-wild study of two identical visualizations shown on a touch-enabled public display (690x390mm), located in the indoor courtyard of a public library at Leuven in Belgium (see Figure 1). The interactive data visualization presented an historical dataset of local bicycle lane usage, which was crossed with historical weather conditions and the occurrence of local events. This dataset and location was chosen because of the close proximity to one of the largest bicycle parking lots in the city center, and the fact that it was the only site in this city where volunteers counted the number of passing cyclists manually during the national cycling month. The visualization aimed to contrast this data to the other locations throughout the city that capture bicycle usage data in automatic, yet concealed, ways. The public visualization was set up in two distinct conditions. The narrative condition embedded a strategy that revealed four distinct insights by way of textual annotations that were exposed sequentially, while the non-narrative condition did not include these narrative annotations.

The graphic design of the visualization was deliberately chosen to resemble the interactive annotated chart titled "*Bubble to Bust to Recovery"* by Bloomberg (Stolper, Lee, Riche and Stasko) in terms of design aspects like font type, color scheme and basic interactive features. The interface conveyed a simplified non-interactive map of the city, indicating the geographic location of three bicycle lane measuring points (see Figure 1, below right on the display), and an interactive chart with three overlaying line graphs, presenting the historical evolution of the bicycle counts (see Figure 2). The narrative strategy was chosen to make use of *phrasing*, which is an individualization technique (Hullman and Diakopoulos, 2011) to address the viewer in a personal manner with textual annotations that complement the graph. Accordingly, the narrative condition was structured as a martini-glass (Segel and Heer, 2010), which follows a tight narrative path of sequential annotations (the stem of the glass) and then opens up for user-driven, free exploration (the body of the glass). As such, the viewer is forced to control the sequential display of the four annotations by way of selecting a numbered (1 to 4) stepper-button, or alternatively the left/right arrows shown alongside (see Figure 2 (1a-d)). As illustrated in Figure 2 (1e), the fourth and thus last annotation appeared together with three colored query buttons, each revealing an additional data dimension (i.e. temperature, precipitation and events) for further exploration. As such, the fourth annotation of the narrative condition was identical to the layout of the non-narrative condition. Two graphical call-to-actions, i.e. a pulsing silhouette of a pointing hand (Figure 2, left on each chart), were included to make passers-by aware of the touch-enabled interactive features of the public display.

The in-the-wild study was deployed during four consecutive days (Tuesday-Friday, 10am-6pm), in alternating time slots of 4 hours, resulting in 16 hours per condition. All user interactions were recorded by way of concealed video recording, which allowed us to capture user behavior and their duration. All interactions on the display were also electronically logged. A concealed researcher observed participant behavior, such as the social interactions and discussions that occurred around the display. When participants left the display, we approached them to report on "*what they had discovered*". This broad formulation as well as its deliberate repetition encouraged passers-by to describe any remembered finding in a patient and considerate atmosphere. We also inquired users as to what made them to approach the display. Then, we asked their previous experience with data graphs, and finished with requesting basic demographic information. We stopped interviewing once the second condition reached the same number of participants (i.e. 27) within the predefined study duration.

As shown in Table 1, we labeled how each user spatially engaged with the public display according to the successive stages of engagement, i.e. Passive, ACtive and Discovery (PACD) (Memarovic, Langheinrich, Alt, Elhart, Hosio and Rubegni, 2012). We consider this model as suitable for our purposes as it considers how passers-by physically approach or observe a display without necessarily dedicating attention to. For instance, a passer-by might only engage with a display passively, such as by just glimpsing or touching the buttons randomly. It is only when they recognize the content to be somehow useful (Müller, Wilmsmann, Exeler, Buzeck, Schmidt, Jay and Krüger, 2009), that they will decide to actively engage with it, such as by more carefully reading a title or inspecting a graph. As the two conditions resemble each other from about a meter distance, we expect no difference in the Passive and Active stages. Further user engagement finally leads to the stage of Discovery, which included at least one meaningful (i.e. not randomly touching or immediately leaving after touching) interaction with the data.

Table 5-1 Parameters of engagement (in white) and of insight formation (in grey), for narrative and non-narrative condition.

| | **Narrative** | **Non-narrative** |
|---|---|---|
| Passers-by | 636 | 497 |
| Passive Engagement | 185 | 142 |
| Active Engagement | 66 | 67 |
| Discovery | 47 | 36 |
| Time in Discovery | 51,1s (SD: 22,2) | 35,9s (SD: 15,6) |
| Meaningful interactions | 57 | 96 |
| # interviews | 27 (14 Male, avg. 41 y.o., 21 SD) | 27 (13 Male, avg. 44 y.o., 22 SD) |
| # insights | 37 | 26 |
| Factual | 8 (21,6%) | 15 (57,7%) |
| Interpretative | 15 (40,2%) | 3 (11,5%) |
| Reflective | 12 (32,4%) | 5 (19,2%) |
| Referring to context | 10 | 2 |
| Detailed | 15 | 5 |
| Comparative | 20 | 18 |
| Overview | 2 | 3 |
| Insights/person | 2,2 (SD: 1,4) | 1,7 (SD: 0,64) |

Two independent researchers who were not immediately related to this research coded the transcripts of the interviews according to a custom insight reporting methodology (Saraiya, North and Duca, 2005; Yi, Kang, Stasko and Jacko, 2008), which was divided in two categories. First, 'insight depth' was interpreted in three subcategories: 1) *factual*, a mere description of data values; 2) *interpretive*, the synthesis of data values with data-independent knowledge; and 3) *reflective*, which includes some personal or emotional connotation. Second, each insight was coded according to the number of distinct data dimensions it referred to, which were separated into three subcategories: a) *detailed*, pointing to one specific data dimension; b) *comparative*, referring to two or more data records that are related with another; and c) *overview*, relating to the visualization itself or beyond, for instance when the insight was extracted from previous knowledge on the topic. For *interpretative* and *reflective* depth insights, we also coded if the insights referred to contextual elements (see Table 1), such as the local government or the cycle-friendly surrounding. It should be noted that any reported insight that corresponded to any of the four provided insights from the annotations in the narrative condition was removed, even when it included some interpretation or reflection, yet except when it was obvious it was not based on the annotation, but on other data.

## 5.3. Results and discussion

### 5.3.1. How narrative design strategy impacts insight creation

*Comprehension:* The process of understanding the graphical encodings or the offered functionalities of visualization can form an augmenting factor for insight creation. While our sample size was too small to make statistically valid conclusions, the results of the narrative condition suggest that the narrative strategy promoted the flow from an active to a discovery-driven stage of user engagement (71%, 47 out of 66), and this during a longer period of time, as shown in Table 1. In the non-narrative condition, less transitions between the active and discovery stage occurred (54%, 36 out of 67), which can be explained as six participants in the active stage mentioned they were *"happy to study the graph as it is"* and felt no need to interact with it, only studying it from a meter distance. In the discovery stage, participants of the non-narrative condition performed more interactions, which means they explored more additional data after inspecting the main chart, similar to previous research (Boy, Detienne and Fekete, 2015). The reported insights of the non-narrative condition remained mostly factual, as these interactions served to understand the functionalities of the line graphs (N=5), and not the meaning they conveyed: "*I am just clicking around to find out how it works".* Notably, in the narrative condition, participants did not report on discovering functionality features. Instead, several participants (N=11) mentioned how they interacted with the line graph to make sure if the predefined narrative annotations corresponded to the data shown in the line graphs, and thus whether the narrative was truthful. Here, the narrative annotations were perceived as suggestions to co-author the visualization, by way of steering how to interact with it.

*Personal reflection:* A narrative strategy tends to promote the duration of engagement in the discovery stage (51,1s in the narrative versus 35,9s in the non-narrative condition) and leads to more personal forms of insight creation. The guiding characteristics of a narrative contributes to lowering comprehension issues (Allen, 2004) in so far that more cognitive effort can be spent in interpreting and reflecting upon the data patterns. As Table 1 shows, more personal reflective insights were reported in the narrative condition (e.g. *"It's not pleasant to cycle there, I would also not take that road*"). Participants seemed to form personal opinions about the predefined insights that were mentioned via the narrative strategy. Although these narrative-derived insights were explicitly excluded from the study results, participants maintained this higher-level reasoning when describing the insights that followed. As such, many insights in the narrative condition were mentioned as interpretations (e.g. "*Maybe they did not consider the amateur cyclists because they are going too fast*") or reflections (e.g. "*I think it's not great living in that street with all that traffic*"). Accordingly, an appropriate guiding visualization narrative has the potential to support lay users to form their own data-driven insights, such as via critically examining the truthfulness of the predefined insights and then applying a similar sense-making process when creating subsequent insights.

*Authorship:* The authorship of visualization is influenced by its context, which encourages more critical reflection via a narrative strategy. The deeper insights of the narrative condition often (N=10 of 37) reflected on the role of the perceived owner of the surrounding environment (i.e. here the local government) in data acquisition and interpretation. In some cases (N=3 of 37), people identified the local government as the 'narrator' of the annotations, e.g. *"They [referring to local government] should come at my mothers' front door to count cyclists".* One participant in the narrative condition questioned the expertise of the perceived narrator, i.e. "*I don't believe they [referring to local government] are right about the peak in cyclists in the fourth week of September*". As such, the narrative strategy lends itself to act as a 'questioning lens' on the data (Dörk, Feng, Collins and Carpendale, 2013; Elsden, Mellor, Olivier, Wheldon, Kirk and Comber, 2016), and on its perceived author. In contrast, in the non-narrative condition, the surrounding environment or a perceived author was hardly ever mentioned in the insights (N=2 of 26).

Furthermore, three participants in the narrative condition linked the perceived authorship to a political goal, e.g. "*they [referring to local government] probably want to close down the cycling path in the Parijsstraat*". Indeed, as deploying a narrative structure in visualization may already suggest some kind of agenda to the viewer (Elsden, Mellor, Olivier, Wheldon, Kirk and Comber, 2016), this suggestion is further augmented by presenting it in a public environment. Overall, these results indicate that deploying a narrative strategy in public environments implies a potentially subjective narrator, which might lead to more biased insights.

### 5.3.2. How public visualization engages passers-by

*Perception:* The content and personal relevancy of a public visualization is determined by the textual title as well as the graphical data representation. For both conditions, the personal interest in the topic of display was the main reason (N=31) for interaction, which was discovered by reading the title (N=19) or inspecting the chart (N=14). Some (N=5) mentioned the chart, independent from the topic, as personal motivation e.g. "*I recognized statistics, which I like to inspect*", while three (N=3) participants explicitly mentioned how the apparent presence of a unique data outlier in the line graph made them engage with the display.

Figure 5.3 A cyclist inspects the narrative, public visualization.

*Social collaboration:* Public visualization is able to promote collaborations between strangers, yet often to share the cognitive effort in comprehending it. Passers-by noticed frustrations of onlookers, which provided a conversation point about how to comprehend the line graphs (N=2, e.g. *"What does X stand for?")* or a hypothesis (N=3), e.g. *"…[she] did not understand why one week had suddenly so much more cyclists, and I thought I could help her with finding out".* Whereas such collaborative efforts have already shown their usefulness (Heer, Viégas and Wattenberg, 2007; Viegas, Wattenberg, Van Ham, Kriss and McKeon, 2007), its practical uptake in online media has shown to be relatively limited. In contrast, social forms of visualization in more physically contextual settings might allow for more opportunistic ways of collaboration.

## 5.4. Conclusion

We discovered how a narrative strategy in relation to contextual aspects overcomes comprehension issues and supports deeper reflection on data, in a more personal manner, thereby connecting the immediate environment as author of the narrative. We propose that our results demonstrate how information visualization can learn from advancements in the domain of public displays as well as from investigating the use of information visualization in alternative contexts of use. Future visualization evaluation studies could therefore consider more qualitative analyses.

## 6. Case study V: Data on Site

In this chapter, we study narrative design strategies (RQ1) and physical interaction (RQ2) via a distributed approach (RQ3), and evaluate how the differing contexts impact engagement and insight-generation (RQ4).

This chapter is submitted to CHI'18 conference on September 19, 2017 as:

Claes S., Coenen J., Vande Moere A. (2018). Data on Site: Distributing a Public Visualization and Polling System over Environment and Users.

Initial insights on this study have been published as a work-in-progress:

Claes, S., Coenen, J., & Vande Moere, A. (2017, June). Empowering Citizens with Spatially Distributed Public Visualization Displays. In Proceedings of the 2016 ACM Conference Companion Publication on Designing Interactive Systems (pp. 213-217). ACM.

## My role

*In 2016, we applied for an OrganiCity.eu experiment grant, which allowed us to develop a public visualization toolkit for citizens, based on the results of previous chapters. During 5 months, and with the helpof Jorgos Coenen, I organized three co-design workshops and several in-the-wild deployments in three different cities: London, Aarhus and Santander. The experiment did not allow us to organize a study of several weeks. Therefore, we sought a Belgian context to study the toolkit for a longer period of time.*

*We contacted the researchers of 'Curieuzeneuzen', a large scale citizen science project on air pollution in the city of Antwerp in Belgium. Results of this study revealed some neighborhoods to reach 'unhealthy' levels of Particle Matter (PM25), of which the Borsbeekstraat was one. Here, a neighborhood committee was organized to raise awareness on the issue. They volunteered to deploy our toolkit for several weeks. As an incentive, they received a PM25 sensor that monitors the particle matters in real-time.*

*The resulting publication is currently a work-in-process, and is authored primarily by myself, with support from Jorgos Coenen Andrew Vande Moere.*


Figure 6.1 Updating the e-ink displays at the façade of one of the participating households.


*Figure 6.3 Deployment of DoS 8 in Antwerp.*

## Abstract

*Internet-of-Things devices allow citizens to appropriate data for their own purposes, such as raising political awareness on a local issue. Public visualization has the ability to engage a wide audience with this data by situating its visual representation in the environment where it is monitored. After an iterative co-design process with citizens, we propose a system that allows residents to distribute public visualizations over multiple displays distributed over different locations, which together construct data-driven storylines. Through in-the-wild deployments in two international cities, we studied how passers-by and residents, which acted as co-authors of the data narratives, engaged with the system. Our findings show how the relationships between passers-by and the residents were influenced by the perceived content, carrier and environment of the system, and tended to inhibit the sense-making process towards the local issue, rather than the data or the insights that were conveyed.*

## 6.1. Introduction

Internet-of-Things (IoT) devices such as the Smart Citizen Kit (Citizen.me) or the Air Quality Egg (Egg.com) allow citizens to appropriate data for their own situated purposes (Balestrini, Diez, Marshall, Gluhak and Rogers, 2015). Whether they are monitoring sudden changes in sound levels around Heathrow airport (Nold, 2015) or capturing the daily patterns of air pollution in Amsterdam (Jiang, Kresin, Bregt, Kooistra, Pareschi, van Putten, Volten and Wesseling, 2016), the resulting data is often exploited to provide empirical evidence in addressing a local issue, to form a quasi-objective basis for discussion with local governmental organizations (Balestrini, Diez and Marshall, 2014), or to orchestrate local political action by deploying data as a catalyst for community-driven dialogue (Balestrini, Diez, Marshall, Gluhak and Rogers, 2015). Instead of the common practice of opening such data and their discussions on an online platform, we propose to present such data sets within the public space itself, in the vicinity of the actual location of its measurement. As such 'public visualization' creates opportunities for a wide range of citizens or civic groups to engage with this data (Vande Moere and Hill, 2012), raise awareness on matters of concern (Dantec and DiSalvo, 2013; Crivellaro, Comber, Dade-Robertson, Bowen, Wright and Olivier, 2015; Taylor, Lindley, Regan, Sweeney, Vlachokyriakos, Grainger and Lingel, 2015), often supported by polling devices to further stimulate social discussion and public debate (Koeman, Kalnikait and Rogers, 2015).

We propose a custom public visualization and polling system to support citizens in triggering civic participation on a local, data-related issue. In order to make explicit the shared authorship and relevance of the messages that are intended by disclosing such data in the public atmosphere, the displays are deliberately spatially distributed over a number of resident home facades (Taylor, Marshall, Blum-Ross, Mills, Rogers, Egglestone, Frohlich, Wright and Olivier, 2012; Koeman, Kalnikait and Rogers, 2015). In order to elicit interactive forms of public engagement, some of the displays are equipped with a polling functionality, allowing passers-by to express their personal opinion on related issues. However, little knowledge exists on how passers-by interpret or engage with a public visualization and polling system that is distributed over the semi-public realms of house façades, and thus situated within the hyperlocal socio-cultural context of the community residents themselves. Here, different levels of context exist, including i) content; ii) the carrier of the content; and iii) the surrounding (urban) environment (Vande Moere and Wouters, 2012).

We thus present the development and evaluation 'Data on Site' (DoS), a public visualization system consisting of multiple sets of wirelessly networked, battery-driven e-ink displays. Each public visualization set contains six individual displays. Each of these displays presents a single data set by way of a graphic or textual representation, such as a line graph, infographic or an anecdote. One set of displays present a data-driven storyline, such as how green areas positively affect air pollution. The sets are extended with a polling device, consisting of three embedded push buttons that each represents a sequential sentiment, such as a happy, neutral or sad smiley. Multiple sets are spatially distributed, while taking particular care that their successive storylines can be read in a narrative way, in that each set presents a different yet related storyline as a particular part of a bigger, overall story. Local champions, who aim to raise awareness on a local issue, can initiate the deployment of DoS and encourage other resident household to 'adopt' a set unto their facade. As such, the DoS system aims to reach a wide range of passers-by, including other community members that do not directly partake in the system, or neighborhood visitors. The DoS system was evaluated in-the-wild, within the context of raising civic awareness on issues concerning 1) supporting the local retail and 2) avoiding hyperlocal, urban air pollution.

## 6.2. Related work

Examples of public visualization often present data that is captured via public polling devices (Valkanova, Jorda, Tomitsch and Vande Moere, 2013; Behrens, Valkanova, gen. Schieck and Brumby, 2014; Valkanova, Walter, Vande Moere and Müller, 2014; Koeman, Kalnikait and Rogers, 2015; Taylor, Lindley, Regan, Sweeney, Vlachokyriakos, Grainger and Lingel, 2015), with the aim of supporting social discussion and reflection on local issues in the community (e.g. (Hespanhol, Tomitsch, McArthur, Fredericks, Schroeter and Foth, 2015; Koeman, Kalnikait and Rogers, 2015; Taylor, Lindley, Regan, Sweeney, Vlachokyriakos, Grainger and Lingel, 2015)). Yet public visualization can also represent other data sources to trigger social discussion and reflection, such as open data of civic platforms (e.g. (Claes and Vande Moere, 2017)) or energy monitors (e.g. (Bird and Rogers, 2010; Vande Moere, Tomitsch, Hoinkis, Trefz, Johansen and Jones, 2011; Valkanova, Jorda, Tomitsch and Vande Moere, 2013)). These data sources provide opportunities to inform citizens more extensively on the issue, such as their own stake in the issue (Valkanova, Jorda, Tomitsch and Vande Moere, 2013). Furthermore, presenting multiple data sources through multiple visualizations, such as a data dashboard, encourages comparison and interpretation of data (Vande Moere, Tomitsch, Hoinkis, Trefz, Johansen and Jones, 2011).

Passers-by can be enticed to discover insights through public visualization when personal relevance of the presented issue is high and boundaries for use are low (Sprague and Tory, 2012). Through conveying stories in data (Segel and Heer, 2010), narrative visualization is a promising approach for designers to ease the learning curve of interpreting visualization (Boy, Detienne and Fekete, 2015) and to increase personal relevance through reflection (Claes and Vande Moere, 2017). Furthermore, narrative visualization has the ability to shift authorship from author to viewer, which encourages passers-by to reflect upon the themes that are embodied by the data (Segel and Heer, 2010). Furthermore, from the resident side, narrative visualization provides support to tell their perspective on the issue based on data (Segel and Heer, 2010; Elsden, Mellor, Olivier, Wheldon, Kirk and Comber, 2016).

Yet when situating narrative visualization in public environments, the surrounding context might be identified as data author (Claes and Vande Moere, 2017). In this environment, the traditional semantic context as established by newspapers or online platforms for decoding and interpreting the visual representation of data, is missing (Offenhuber and Seitinger, 2014). The public environment however offers other distinct contextual cues that help the sense-making process of visualization (Vande Moere and Offenhuber, 2009; Vande Moere and Hill, 2012). Attaching public displays to the façade of citizens' homes connects the interpretation of the content to the pre-existing, complex social relationships of the neighborhood it is located in (Wouters, Huyghe and Vande Moere, 2013). Locals who are familiar with the socio-cultural dimension of the environment, for instance, may connect tacit aspects to the visualized data (Vande Moere and Wouters, 2012). The location may therefore become a contextual cue that changes the interpretation and suggest social and political values and assumptions (Dörk, Feng, Collins and Carpendale, 2013; McInerny, Chen, Freeman, Gavaghan, Meyer, Rowland, Spiegelhalter, Stefaner, Tessarolo and Hortal, 2014). Indeed, the meaning that the public visualization evokes is entangled with our perception of the social world (Elsden, Mellor, Olivier, Wheldon, Kirk and Comber, 2016).

Besides influencing the interpretation of data, the public context also affect how passers-by behave with public displays, such as being motivated to interact when seeing others interact (Wouters, Downs, Harrop, Cox, Oliveira, Webber, Vetere and Vande Moere, 2016) or embarrassed to interact (Schieck, Briones and Mottram, 2008). Also the social dimensions of the environment, such as social pressure, influences interaction behavior of passers-by (Vlachokyriakos, Comber, Ladha, Taylor, Dunphy, McCorry and Olivier, 2014).

## 6.3. Exploring the design space of Data on Site

The first, more exploratory part of our study was framed as an experiment within OrganiCity.eu, a European H2020 project that aimed to facilitate experiments on how citizens can collaboratively work with urban data towards urban challenges, which allowed us to co-design the features of DoS and pilot test its real-world usability within three international cities in Europe.

We organized co-design sessions to gain understanding of how residents want to communicate a local issue in terms of 1) data and how to visually represent it; 2) their home as the carrier of a public visualization and polling system; and 3) location, where to position it in their neighborhood and how to connect it to the location's social dimensions. In the city of London (UK) 8 residents of 1 neighborhood (4F, avg. age 43, SD 12) participated. In the city of Aarhus (Denmark), 3 local champions (1F, avg. age 41, SD 4) of 2 distinct neighborhoods participated. The discussions fueled by a mapping method were annotated on a map of the neighborhood, and summarized with the participants (Huybrechts, Dreessen and Schepers, 2012). Afterwards, we analyzed and thematically categorized the findings through a grounded theory approach (Glaser, Strauss and Strutzel, 1968).

Figure 6.3 Co-design workshop in London.

*Implications for content design.* A public visualization needs to be able to present different types of data representation, including: 1) data graphics techniques such as line graphs or scatterplots, as these visualization types relate to the general expectation of how statistical evidence should be presented in clear, transparent and truthful ways; 2) visual depictions that provide additional narrative context and meaning, such as comparisons between trends of different cities or time of day; 3) infographic-style bite-sized facts and statements that can easily remembered, such as '*Air pollution is responsible for 80% of premature deaths*'; and 4) qualitative calls-to-action that are contextually relevant, such as anecdotes, e.g. '*I have to clean my façade every year because of the filthy polluted air*' or solutions, e.g. *'Get your shopping delivered by cargobike instead of by a polluting car'*.

*Implications for environment and carrier design.* Participating residents were open to the idea of installing a public visualization system unto their own home. Yet they also recognized opportunities in locating these devices in other 'semi-public' locations, such as the school of their children or the hospital where they work. They expected the data could then reach more people and become appropriated in more civic contexts.

The identified need to combine different data representations in multiple contextual situations, led us to the idea of deconstructing a single public visualization display into multiple, smaller displays that could be easily rearranged or moved around.

## 6.4. Adding the perspective of passers-by

First, we developed and evaluated the use of a single public visualization display consisting of multiple data representation types, in order to get a better understanding of how passers-by consumed such seemingly fragmented information. The content thus included a general title, a line graph that represented NOx values over one week, the opinion of a local citizen and several bar charts that presented NOx data of the previous day from comparable cities. We attached the mock-up on the fence of a busy passage in London, and on a window of a public library at a university's campus and on a square in the city center in Aarhus to test multiple contextual situations. We stopped passers-by (in London N=13, 9F, AVG. 35y.o.; in Aarhus, N=32, 16F, AVG. 30y.o.) and asked them what they learned from the public visualization. We deliberately formulated this in an open way, to allow the expression of spontaneous impressions that potentially relate to the environmental context. Citizens of London were generally concerned with the presented issue, while citizens of Aarhus felt not aware of any air quality problem. Despite this sentiment, 5 citizens in Aarhus were surprised to discover the air quality of their city to be comparable to London, which prompted them to inspect the rest of the display more closely. In London, the "air quality data" title already raised expectations of negative trends, which already inhibited four passers-by to further engage with the rest of the display. 19 Citizens only inspected the bar charts and ignored the line graph as they expected it to be too complex to interpret. In three cases, the textual local opinion acted as a starting point for the further inspection of the display.

Figure 6.4 Exploratory in-the-wild deployment in London (above) and Aarhus (below).

We also asked passers-by if and why they were motivated to install a similar public visualization on their own house facade. In Aarhus, 8 passers-by (of a total of 32) reported they would be motivated to attach the public visualization at their facade, as they believed more citizens should be informed on the issue, while 4 passers-by mentioned this to be the task of the government.

*Implications for content design.* Deconstructing a single public visualization display into a variety of types (i.e. textual annotations, opinions, numerical facts, line graphs, infographics) that are contextually related, act as different points of entry and data consumption (e.g. discover a surprising comparison, read a neighbors' perspective on the issue) that together appeal to the interests of a wide range of citizens.

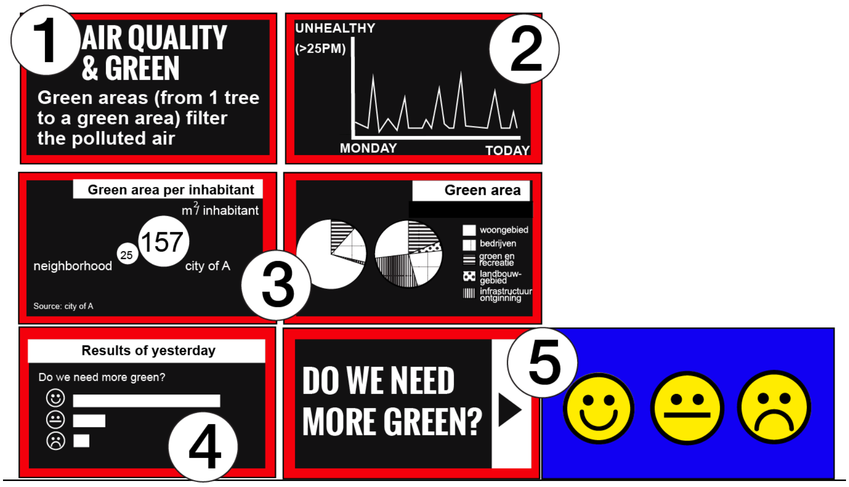



Figure 6.5 The storyline on air quality in relation to green areas on a set of DoS displays.

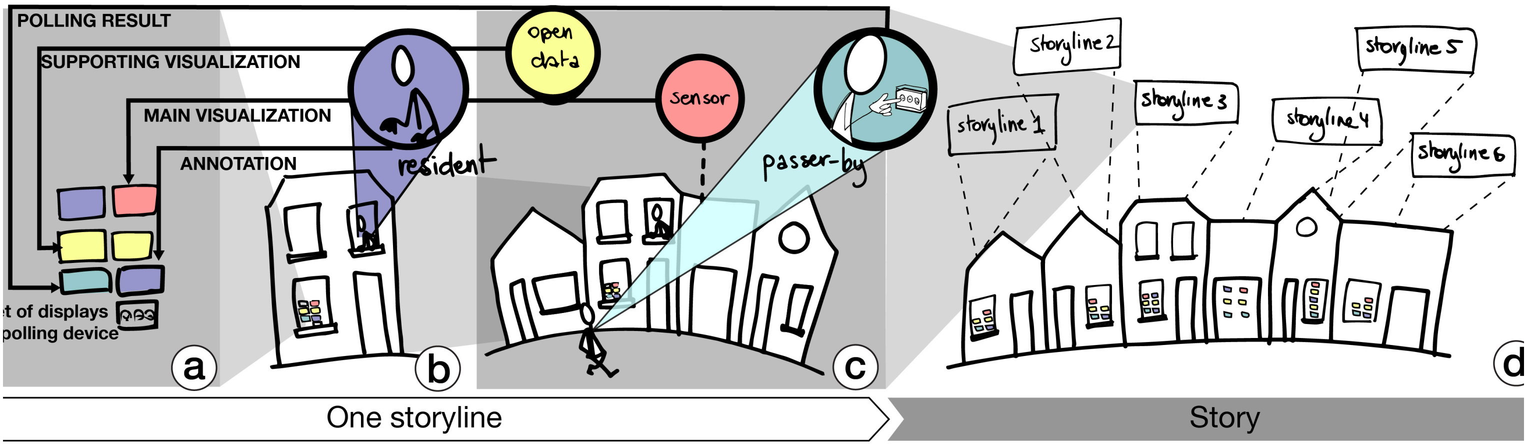



Figure 6.6 Interaction design of DoS: visualizations presented on set of displays (a) on the window of a residents' house (b) in a neighborhood (c) are guided by one storyline. In a neighborhood, several storylines exist, which together form one story (d).

## 6.5. The Data On Site system

We describe the DoS system in term of its intended interaction design and its technical infrastructure.

### 6.5.1. Interaction Design

Each set of six displays (see Figure 6.6) presents a particular perspective on a local issue by way of a specific thematic storyline. Each storyline is depicted by six data sets, originating from local sensor streams or derived from open data repositories, as well as more qualitative opinions from participating residents and passers-by (see Figure 6.5). Each storyline generally consists of: 1) a title that introduces the thematic storyline within the general issue (e.g. Air pollution and the impact of green areas); 2) a main visualization (e.g. a historic line graph on one-week Particle Matter measurements); 3) supporting visualizations or textual annotations (e.g. a textual annotation stating the impact of green combined with an infographic on the number of green areas in the neighborhood, see Figure 6.5), 4) a bar chart that presents polling results (e.g. on the desire to have more green areas), and 5) an annotation by the resident (e.g. the question if passers-by would like more green areas in the street?). On a set equipped with a polling device, this annotation included a concrete question to passers-by as formulated by the resident household who hosted the visualization. On the other sets, this annotation was a personal statement based on reflecting upon the visualized data by the resident household. Passers-by were then able select a happy, neutral and sad smiley, and contribute their opinion through a simple push of a button, which caused an integrated LED to light up.

The electronics of a display are encapsulated by a custom, colorful and 3D printed casing (see Figure 6.9). A display can be attached to the façade either externally through fixating the casing to a glass pane, or internally by gluing the casing to the inside of the glass window and fitting a sticker that hides the outer edges. As shown in Figure 6.6, each set of displays can be freely arranged in terms of layout, such as to adopt to the architectural qualities of a façade.

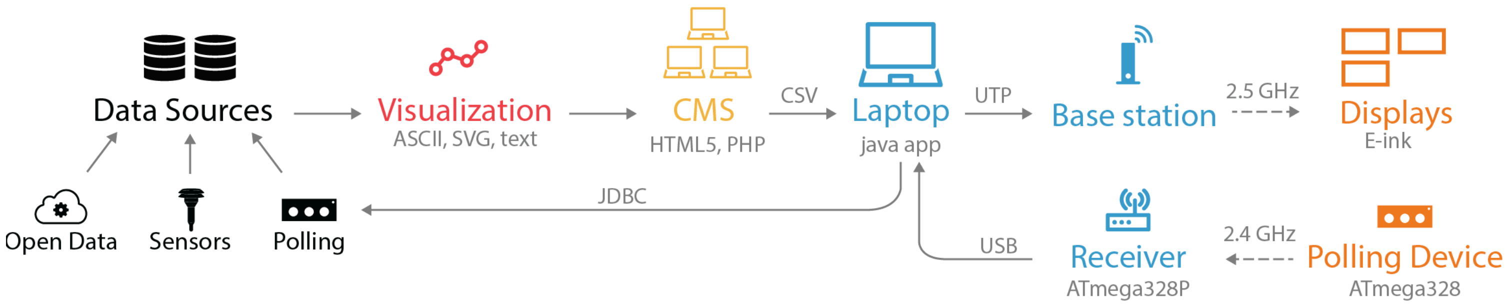



Figure 6.7 The DoS system aggregates data and creates visualizations that form storylines. These storylines are shaped through a CMS and spread to distributed displays. Polling devices collect opinions, which become data sources in the storylines.

Multiple sets of displays can be spatially distributed over multiple façades in a neighborhood. Typically, a participating resident household is selected based on the location of their house facade, in terms of 1) physical aspects, such as how the façade is visible for passers-by from further away or when they are seated on a bench at the public square; 2) how the facade is situated in a specific rhythm of neighboring displays (e.g. each third façade); or 3) its social meaning, as the home of the person championing the local issue, or being community newcomer. Finally, the spatial succession of the different sets also provides a cohesive narrative that potentially signifies the sharing of concerns of multiple neighbors. Next to the set of displays, A5-sized printouts introduced the workings and motivations behind the whole public visualization system. A dedicated webpage offered a more detailed introduction to the project, and pointed to an email address for any inquiries or comments.

## 6.6. Technical Infrastructure

The technical components that comprise the infrastructure behind the DoS system are summarized in Figure 6.7. Real time and evolving data (e.g. from local sensors and polling) is automatically collected on a daily basis and rendered in pre-defined visual representations. Non-time sensitive data from other open data sources (e.g. green areas in the city) were visualized in advance. In response to the outcome of the design space exploration, DoS deliberately employs visualizations with varying levels of visual complexity (Sprague and Tory, 2012) ranging from a single number over infographics to line graphs or bar charts, to appeal to the expectation of passers-by but also provide bite-sized facts. Through a custom web-based content management system the researchers build thematic storylines using these visualizations, and residents are given the opportunity to select one of these storylines on a daily basis and provide a personal annotation.

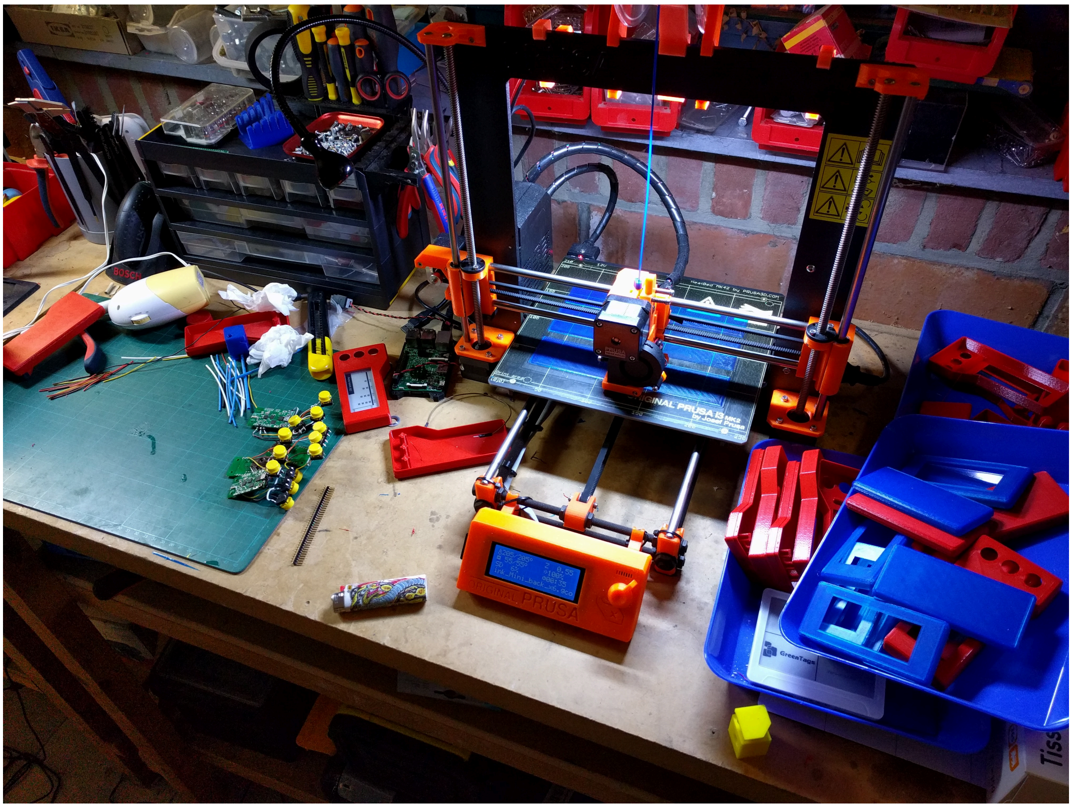


Figure 6.8 Developing the prototypes: 3D printed plastic casings in red and blue (right, in blue box), 3D printer (middle), soldered buttons on the microcontrollers (left, yellow button caps).

The display devices for the distributed visualizations were inspired by technology commonly used in electronic shelf labels. Each display device consists of two components that operate with very low energy usages; an e-ink display (i.e. 2.9 inch, 296x128 pixels, dot matrix) and a radio to enable wireless networking capabilities (2.5GHz). E-ink displays provide good readability even in bright daylight and have become relatively affordable, making them ideal to be used within the volatile conditions of public space. The displays are updated via a custom base station broadcasting on 2.5 GHz, which is connected to an on-site laptop. In practice, a researcher toured the neighborhoodthis equipment every day to update all the displays wirelessly. Alternatively, a mesh network of base stations could cover the entire area. A custom electronic base station connected to the on-site laptop that is located in the vicinity wirelessly receives button presses. The received presses are inserted as votes in an online database through a Java database connector.

### 6.7. Methodology

Our in-the-wild case study applied a mixed method approach, to investigate the impact of the system on two user groups: 1) the participating residents, and 2) the passers-by.

**Residents.** We provided DoS to local champions for them to raise awareness around a local issue that could be evidenced in data. These champions took it upon themselves to recruit community members in the neighborhood, which we coin as 'residents', to host the public visualization. We interviewed residents in an informal way at least 2 times during each deployment. After each deployment, a semi-structured interview was conducted that took approximately 45 minutes and revealed their overall experience with the public visualization system, any gained insights on the daily storylines, and the perceived influence on public debate.

**Passers-by.** DoS engaged different types of passers-by, including non-participating neighbors, visitors and daily commuters. One researcher observed the behavior of passers-by in a concealed way, by sitting on a bench or acting as a casual pedestrian. The engagement of passers-by with the DoS system was categorized according to the PACD model, established in public display evaluation research (Memarovic, Langheinrich, Alt, Elhart, Hosio and Rubegni). We thus interpreted *passive engagement* as turning one's head towards a display, *active engagement* as stopping to take a look and/or reading a single display, and *discovery* as reading (parts of) the storyline and/or pressing a polling push button. When passers-by who engaged with DoS left its vicinity, we approached them for a semi-structured interview (approximately 5 minutes), asking "*what they had discovered*". This broad formulation encouraged passers-by to describe any remembered insight or finding. Passers-by who did not engage with the DoS system were asked if they had noticed the displays, and why they ignored them. We also queried all passers-by about their expectations, and any motivation or inhibitor to actively engage with the displays (Sprague and Tory, 2012). Lastly, we asked if they noticed the displays on a previous occasion, and noted down some basic demographic information. Two researchers


Figure 6.9 DoS attached to a shopping window in the city of Santander.

independently coded the data insights of participating passers-by (and residents) according to whether they referred to the environment (e.g. *"The pollution levels are high because there were a lot of cars today"),* to their personal situation (e.g. *"Maybe I should not have went out with my baby yesterday as air pollution impacts his health"*), or to the content or issue in general (e.g. *"Air pollution is not really a problem in this city"*).

## 6.8. Pilot study

In the context of the OrganiCity project, the city council of Santander (Spain) asked us to deploy the DoS system to raise support for their smart city platform. This real-world case study allowed us to test the usability and technical stability of the DoS system, and whether and how it would perform when being appropriated by residents and passers-by. 4 Local shopkeepers in a retail area were recruited to deploy the public visualization and polling system during four consecutive days. The overarching storyline departed from the question *"Do you know Santander's smart city platform?",* which was presented on one display. Two of the six displays revealed ideas generated via this platform (e.g. mobility, spare time, etc.) through bar charts; two displays presented polling results, and one display showed the opinion of the shopkeeper. The shopkeepers also arranged the displays on the façade of the shop on a daily basis.

Daily interviews with the shopkeepers quickly revealed how the issue that the city council had pushed forward was irrelevant to the shopkeepers (e.g. *"Nobody knows this smart city platform, so they [customers] don't care").* Therefore, we decided to co-create together with the shopkeepers a locally more relevant storyline, and chose data and facts that revealed the benefits of shopping locally. One display of this storyline consisted 2 pie charts that presented the economic return to the local community. Two displays cited annotations that the condition of the shopping streets in the center are going to be improved; two displays presented the same content as on the first day (retrieved from Santander's smart city platform). The interactive display revealed the polling question "*I like to shop locally"* (see Figure 6.9); and one display showed the polling results. The subject of local retail proved to increase the interest and


Figure 6.10 DoS 6: Receiver of polling devices connected to mini computer behind the window (left) and researcher with laptop and base station (right) to update the displays.

Table 6-1 Overview of demographics of participating residents of case study 2.

| Street | DoS | Age | Gender | Profession |
|---|---|---|---|---|
| St. A | 1 | 52 | M | Electrician |
| St. A | 2 | 38 | M | Researcher |
| St. A | 3 | 28 | F | Student |
| St. B | 4 | 25 | M | Fitness instructor |
| St. B | 5 | 48 | F | Lawyer |
| St. B | 8 | 42 | F | Healthcare professional |
| St. C | 6 | 31 | M & F | Architects |
| St. C | 7 | 27 | F | Teacher |

participation of customers as on the second day 14 passers-by were participating in the discovery phase versus 2 on the first day. This experience demonstrated how the importance of the perceived relevance of a civic issue, and in particular its meaningful relationship to the hosting residents who directly and indirectly motivated people to engage with the system, directly affects the participation rate.

*Passers-by.* We observed 3 passers-by who were not customers inspecting the displays during the 16-hours when shops were open. 12 Customers participated in the poll after visiting the shop. In contrast, during lunch break when the shops were closed (i.e. 4-hour observations), a total of 31 passers-by participated. According to 3 of the 4 shopkeepers, passers-by felt embarrassed to inspect DoS when the shops were open, which we believed to be the result by the social embarrassment caused by visually obscuring the retail window for other potential customers. Shopkeepers also reported how customers voted to express a positive sentiment towards the shopkeeper, as opposed to truly responding to the poll. Accordingly, we learned how the perceived ownership or purpose of a display plays an important role in motivating passers-by to engage. During this pilot, the polling devices were physically embedded in the same casing as one of the displays (depicted in Figure 6.9). On the first day of the study, the polling device at one of the shops was stolen. This caused us to separate the polling as distinct devices.

*Residents (here shopkeepers).* Shopkeepers wanted to display positive aspects. On the first day, they expressed critique (e.g. *"The city council should invest in the public space surrounding local businesses"),* while on the last day they presented small talk (e.g. *"Nice weather, nice sales!).*

## 6.9. Case study

The neighborhood committee of street A. (see Figure 6.11), a group of neighbors in the city of Antwerp consists of citizen concerned about the levels of local air pollution, as a scientifically-backed one-month citizen science study (Van Brussel and Huyse, 2017) revealed very unhealthy PM25 values for their street according to WHO standards (WHO, 2005). The committee's aim is for the street to become blocked for non-local traffic streams. As such, the committee showed interest in collecting more and real-time data-based evidence on air pollution, and to share these measurements with the greater neighborhood in order to raise more widespread awareness for

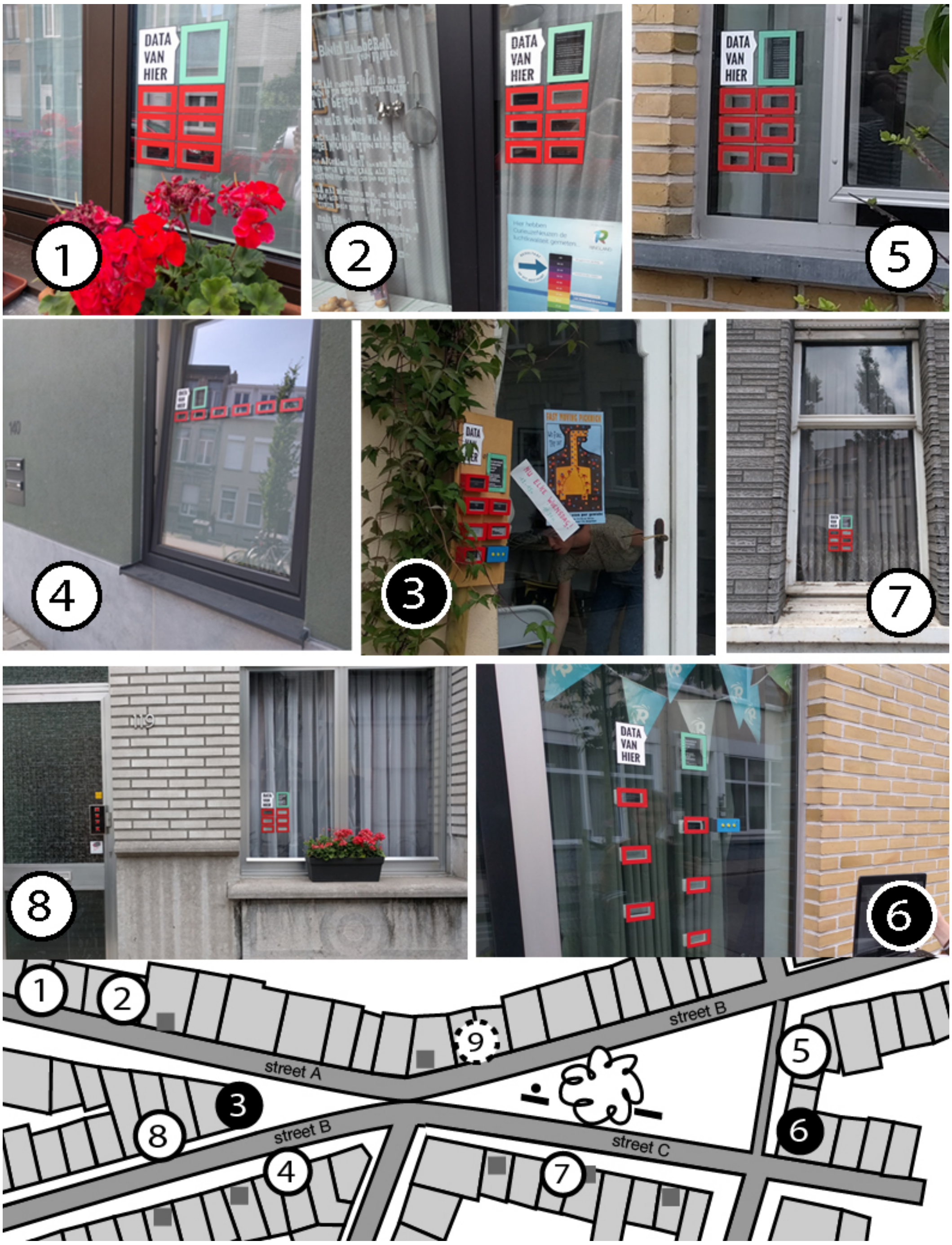



Figure 6.11 Neighborhood in A. The black and white circles present the DoS locations. The residents of the black circled number deployed the polling device.

the issue that could lead to more robust voluntary support structures. Accordingly, we considered it fair to reward their participation in the study by offering an outdoor PM25 sensor, from which the data was used in DoS.

As illustrated in Figure 6.11, eight sets of DoS were distributed around a central public square where street A crosses streets B and C. This public square is visited by members of the wider neighborhood, as it hosts public waste containers, three skate ramps, benches, a large tree and a grass field. Accordingly, we considered the infrastructure as ideal comfort and social spaces (Fischer and Hornecker, 2012) that could prepare and motivate passers-by for interacting with the displays . First, we selected 3 locations for DoS around the public square, i.e. DoS 3, 5 and 6 (see Figure 6.11), of which 3 and 6 was equipped with the extra polling device. Second, the locations of DoS 4, 7 and 9 were chosen to amplify the spatial distribution by creating a rhythm, although unforeseen circumstances caused nr. 9 to drop out the study. Third, the choice for the last remaining locations was based on the social situatedness of the system, as DoS 1 and 2 were the homes of local champions.

The first three days of deployment were considered as pilot to test the robustness of the technical functionalities, during which a number of networking issues were fixed.

## 6.10. Results

The DoS system was deployed for 20 continuous days. Resident 1 (R1) left on holiday after 13 days of deployment. His display set was adopted on request by the household of DoS 8 who continued the study for the last 7 days. We observed the public square for 13 hours, divided over 9 days of the deployment. In total, 30 semi-structured interviews were taken of which 20 with passers-by (7F, 41 avg. age, 19 SD) and 10 with residents (including 2 interviews in pairs). Of those 20 interviews, 7 turned out to be neighbors living in the same streets (their homes are indicated with squares on Figure 6.11). 8 Interviews were conducted with passers-by that casted a vote, 8 with passers-by that only engaged with the visualization and 4 with passers-by that ignored DoS.

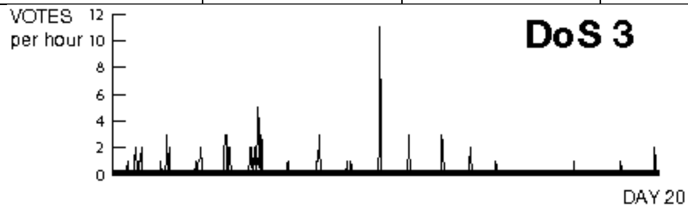
To better structure the relatively complex and contextual interplay between the different user groups, all results and discussions are structured based on the relationship of the passer-by or the resident with the content, the carrier or the environment of the DoS system, as depicted on Figure 6.12.

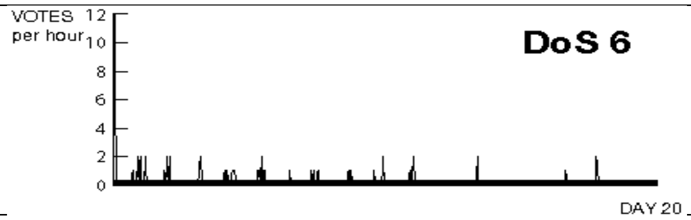
### 6.10.1. Passers-by and content

We observed how passers-by, confronted with multiple displays showing a range of content types, seem mostly interested in bite-sized visualizations. 8 Interviewed passers-by (N=20) declared how they first read the title, glanced over the line graph on particle matter (PM25), and then noticed the text of the last display, which contained the personal opinion of the resident. 4 of those passers-by told how they skipped the displays with the visualizations as they already felt sufficiently informed on the matter, while 4 other passers-by reported to be mainly motivated by the personal opinions and infographics as they expected the line graph visualizations take too much effort. In contrast, the prospect of interpreting visualizations was a key motivation for 2 other passers-by (N=20).

Table 6-2 Observed number of passers-by at DoS 3, 6, 6 and 7 for a total of 13 hours, categorized according to PACD model (Memarovic, Langheinrich, Alt, Elhart, Hosio and Rubegni, 2012), and the number of votes, in total and according to time.

| DoS | 3 | 5 | 6 | 7 |
|---|---|---|---|---|
| Passing | 170 | 330 | 162 | 210 |
| Passive | 0 | 9 | 6 | 8 |
| Active | 6 | 2 | 2 | 2 |
| Discovery | 5 | / | 2 | / |
| | | | | |
| Votes | 41 | | 79 | |




Passers-by engaged with the content based on its perceived personal relevance. As the weather conditions were stable during the first two weeks of deployment that is with a stable historic temperature curve and no rain, the visual representations of local climate data did not reveal unhealthy conditions of air pollution. Accordingly, P8 stated that *"I saw it displays the amount of rain, but it hasn't rained for the last 5 days, so I do not need to look into that".* Other passer-by related their interpretation of the air pollution to the time of year (e.g. P4 *"summer holidays just started, so less cars that pollute")* or particular events (e.g. "*the road works result in less cars")*. We also learned how 7 passers-by (N=8) that casted a vote, inspected the visualizations before pressing a button, e.g. *"I want to be sure I have the right information to vote".*

### 6.10.2. Passers-by and carrier

The relative location of the displays affected the level of active engagement behavior. As evidenced in Table 6-2, both passive and active engagement occurred most with DoS 3, 5 and 6. 5 Passers-by reported they were passively engaged with DoS 5, 6 or 7 but did not want to actively engage with the content, as it would appear they were trying to look inside the homes. In 2 occasions, we observed how passers-by took a picture of the display constellation, a strategy to read and study the exact content during a later point in time.

At DoS 6, 4 passers-by reported to feel unsure they were allowed to press a polling button, as they reported the size of the displays to imply it to denote a personal device, or that its outer design resembled that of a doorbell, causing them to doubt what would happen after a button press.

### 6.10.3. Passers-by and environment

Passers-by tend to relate the overarching issue to the assumed social status or intentions of the resident. As shown in Table 6-3, 7 insights of passers-by reflected on the personal relevance of the overall issue, e.g. "*It is important to know the air quality levels for the health of my children"*; 6 on the relationship with the resident e.g. "*They [referring to residents] want us to stop polluting with our car*"; or 10 on the city, e.g. "*The city council only measures the air pollution when it is summer, but then there is no pollution, just as now"*. 4 Insights revealed how passers-by reflected on the specific characteristics of the resident in relation to the data, e.g. *"I think there must be a doctor living here, as it is about health and air pollution".* The status of the residents also influenced how passers-by trusted the content, as the data at DoS 3 should be taken *"with a grain of salt, as it's at the artists' place*", mentioned by passer-by 14 (P14). P14, however, equally reported to realize the overall system was *"meant in a serious way as the architects also display it*", meaning the displays at DoS 6. Furthermore, personal reflections also led to personal feelings of guilt, such as *"I own a car but I do not use it often!"* (P7), indicating how most passers-by related the overall issue to their personal experience.

The motivation to engage with the public visualization was influenced by the (perceived) personal social relationship of the passer-by with the individual resident household. R2 reported that her friends said they did not engage with her set of displays because they expected it to be activist. Yet these friends mentioned her they engaged with DoS 4, e.g. *"they did not expect of that owner, they were surprised in a good way by him and that made them interested in the issue, which made them questioning me about the issue"*. Similarly, 3 interviewed participant-neighbors expressed they were not interested in the issue at a first glance, but became motivated to inspect it because their neighbor put it up. However, this relationship can also have inverse consequences. P20 felt their neighbors are already judging her for the traffic intensity and air pollution "*I feel how they look at me when I am trying to park my car, but I cannot afford a fancy job in the city centre like they, I need to go outside the city"*, which inhibited her to engage with DoS.

The physical location of the polling devices versus common urban infrastructure seemed to influence the polling results. As shown in Table 6-2, 79 genuine (i.e. each vote casted within 5 seconds of previous vote were discarded) votes were registered at DoS 6 versus 41 votes at DoS 3. Table 6-2 also shows how the majority of button presses occurred in the evening (after 8pm). Here, we observed groups of people voting together, after they first were hanging around at the public square. At DoS 3, we observed how citizens noticed DoS during the act of disposing waste at the garbage cans, and engaged with DoS by casting a vote after this act, resulting in votes that are spread over the day.

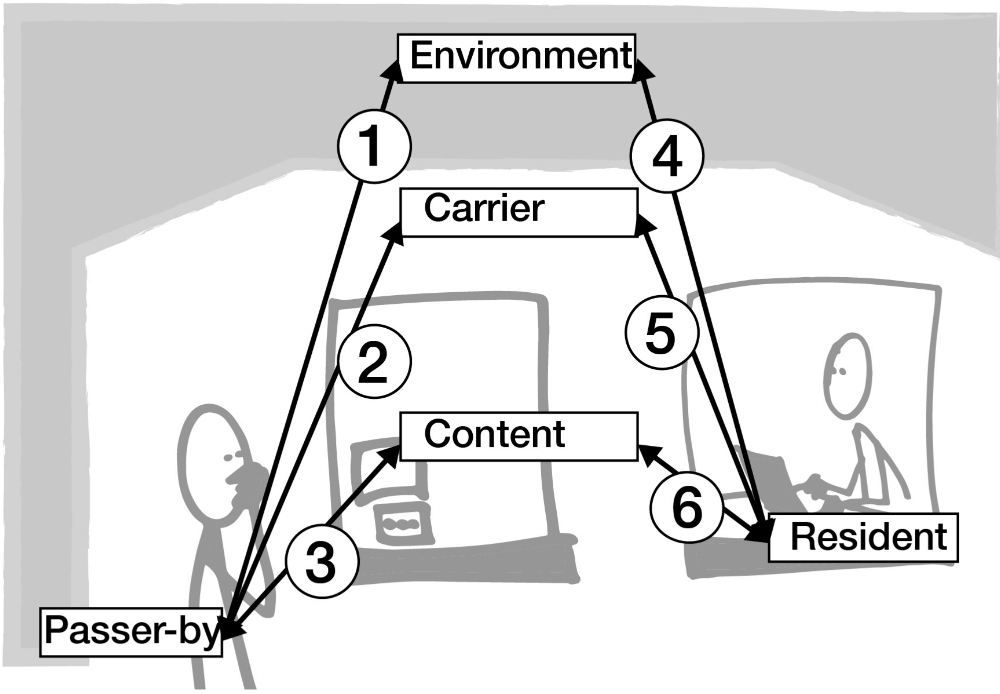



Figure 6.12 Relations between passer-by and (1) environment, (2) carrier and (3) content, and resident and environment (4), carrier (5) and content (6).

The polling seemed influenced and potentially biased by how residents would interpret the expressed preferences. Although two passers-by wanted to vote 'unhappy' on the question *"What do you think of children playing during traffic hours?",* they reported to feel uncomfortable to vote this way, as it would express a 'negative' feeling towards the resident. As a result, one of them voted 'happy', and the other did not cast a vote.

Passers-by weighed the relevance and their engagement with the issue to current, local events. After the first week of deployment, riots between a young, foreign population and the police continued in the neighborhood during 5 days. 4 Passers-by reported these riots to be more important than the issue of air pollution, because *"this is happening at this very moment and not somewhere in the future"* (P5).

### 6.10.4. Residents and environment

Fixed, daily update moments cause room for social discussion. Neighbors and residents requested more information on the project during the daily update moments. Five neighbors regularly (i.e. more than 3 times) approached the researcher to ask about the project in general, or specific *"whether there is sufficient proof of the air pollution yet"* (P7). In five occasions, these informal question moments caused social discussion on the issue between neighbors. Despite the vicinity of all display sets, two residents reported they would like an overview of the opinions and questions of other residents, as this would help them to 'feel part' of a bigger project.

Figure 6.13 DoS nr. 7 on the window next to the entrance door of the grey house (right).

### 6.10.5. Residents and carrier

Designing and determining the layout of the displays was a non-obvious task for residents. Residents of DoS 2, 3, 4, 6, and 8 decided for themselves the location and arrangement of the set of displays on their window or façade, and based their designs on previous encounters with passers-by or experiences of hanging posters. The remaining 3 residents asked the researcher to do it for them. In case of R3, we had to consider the lack of a window facing the square, for which we constructed a custom wooden notice board. R4 and R6 personalized the arrangements of the displays by spreading the displays over the entire window. R3 and R8 reported after the deployment period how they would extent the DoS system with tailor-made casings as a way to hold specific viewers' attention. R8 would have liked to be able to add Arabic characters on the displays as this would appeal to a broader audience. This resident also imagined more Arabic embellished casings for the displays, as she believed it would become more beautiful. R1 and R3 requested bigger displays to target automobilists, as they form the cause of the issue.

### 6.10.6. Residents and content

The personal opinions uploaded by residents and shown on the sixth display had hyperlocal relevance, such as by making links to current events. Five residents regularly (> 7 times) updated their opinions in relation to the given storyline. R5, R6 and R7 consciously contemplated every other day (10 times in total) on the opinions, e.g. "*As a young adult, I think it's normal to be healthy. What about the future? What am I doing by choosing to live here?"*. The

Table 6-3 The number of insights coded according to content, environment and person.

| Insights that: | 20 Passers-by | 8 Residents |
|---|---|---|
| Refer to Content | 4 | 8 |
| Refer to Environment | 16 | 2 |
| Refer to their Person | 7 | 3 |
| **Total insights** | **27** | **13** |

opinions were often linked to actual situations in the neighborhood, *e.g. "The road works cause less traffic and thus less pollution. For how long though?".* After a week of deployment, residents were allowed to choose their own storyline based on personal relevance. 6 Out of 8 residents chose the theme of health and children, while two others chose health. 3 Residents only updated the opinions once or twice. R6 reported to have moral issues to pose a question that implies a negative answer, yet found it difficult to rephrase some questions in a positive way without losing the expression of a concern.

## 6.11. Discussion

Based on the same relational interplay depicted in Figure 6.12, we discuss design considerations for the bottom-up public visualization of data-evidenced civic concerns.

### 6.11.1. Passer-by and environment

Public visualization encourages passers-by to reflect on the overall local issue – more so than the patterns that might be revealed in the visualizations themselves. As passers-by even can become self-conscious of their stake in the issue, they feel embarrassed towards the resident and neighbors that push the issue in the public realm, potentially prohibiting proper engagement or unbiased polling with the system. For instance, our results revealed how some passers-by felt it would be hypocritical of them if they would participate in the poll, as they had the impression the residents were directly pointing a finger at them. The private character of the carrier, i.e. a house façade, gives passers-by the feeling of being personally addressed by its inhabitants. In that respect, publicly owned locations, such as urban infrastructure or public buildings might be more suited as hosts of public visualization as they represent more neutral and commonly shared territory. On the other hand, designers can exploit the more personal social dimension of public visualization ownership to elicit particular reflection on the overall issue.

For instance, the social relationship of the passer-by versus the resident increases passive engagement and reflection on the overall issue. As with any public display, public visualization is challenged by the 'display blindness' phenomenon, which describes how passers-by decide upon engaging with a display based on the expected relevancy of its content (Huang, Koster and Borchers, 2008). By locating public visualization unto a resident's home, a neighbor or local passer-by assumes the content to be locally relevant to such degree that they at least passively engage with it. Depending on their own stake or interpretation of the overall issue, and how they perceive their relationship with the resident, passers-by become motivated to engage with the displays in a more active way. In some cases, this caused the passer-by to find personal relevance in the issue, e.g. *"I did not know my neighbors find this topic so important, I should deepen into the problem as well".* This social relationship can also be augmented with the reputation or occupation of a resident, which can particularly affect issues of trust, such as *"When the engineers put it up, it must be serious".* Naturally, this relationship can result in adverse effects, such as when conflicting opinions between passers-by and resident exist.

By distributing public visualization over different, distinct types of resident statuses, such as local champions, owners or tenants, newcomers, immigrants, etc., a spatially expanded *landing effect* can be created. Typically, the landing effect is limited to the area directly in front or between two public displays, where the interactivity with the first encountered display is only noticed after passing causes the second to be noticed sooner (Müller, Walter, Bailly, Nischt and Alt, 2012). Our results demonstrate this landing effect also occurs between two types of residents. A passer-by might be inhibited to engage because of particular social conflicts at one resident location, yet might feel positively surprised by the participation of another resident. Accordingly, by distributing multiple entry points to public visualization over well-considered physical and socially meaningful locations, a wide range of potential motivating factors can co-exist that promote engagement.

Implied negative social sentiments in relation to the resident can inhibit a passer-by to participate in a public polling. Passers-by felt generally not comfortable with disagreeing with residents, or even choosing an unhappy smiley as an answer on a polling question that was perceived to be formulated by a resident. This conflict of motivation probably caused the polling results to be biased. Potential solutions include disclosing the anonymity of polling results, or restricting questions that are more neutral – yet probably also less provocative and engaging. Some passers-by even voted with the positive (happy) answer without reading the question, only to 'like' the project in general or leave a token of appreciation to the residents. Therefore, public polling that links authorship to local peer-level stakeholders like residents seems to cause particular conflicts of interest, in so far that we believe that these should probably be hosted in a more neutral and publicly owned space. However, such shift then opens issues about perceived ownership, and a potential clash in co-existing bottom-up initiatives like DoS with official, and potentially conflicting, campaigns in the same space.

The distribution of content via multiple storylines over the physical environment did not equally cause the spatial distribution of passer-by engagement. In fact, we did not encounter a single passer-by that engaged with more than two set of displays, even when they were aware of the difference in storylines over the different display sets. Perhaps we should have chosen a more differing, stepping-stone narrative structure to better exploit the spatial distribution, such as adding a game or quest to discover all displays, or an overall narrative that only makes sense when multiple displays are read. Future work might further discover more proper applications of spatial content distribution.

### 6.11.2. Passer-by and carrier

Carriers with indistinct or ambiguous physical characteristics inhibit engagement with public visualization. Passers-by tend to be embarrassed to inspect displays attached to windows without curtains, as they felt other passers-by would judge them as a 'peeping Tom'. Similarly, when the windows were dirty, passers-by were not motivated to actively engage, as they did not want to be perceived as judging the cleanliness of the resident's home. We learned how a simple architectural feature as a window can create uncertain situations for a passer-by, as they consider who might be looking (and judging) from inside, or might be interpreting their interaction with the window (and thus the residents) from the outside. An ideal carrier should therefore establish the physical means for passers-by to engage with the content and polling in a more 'private' setting, for example by exploiting a protruding wall, or surfaces with less obvious ownership.

#### 6.11.3. Passer-by and content

Interactive polling promotes the discovery of public visualization. Our results show how the display sets without the polling feature less often facilitated discovery engagement. Designers can therefore deploy interactive polling as a conscious strategy to encourage people to engage with multiple facets of the underlying issue. However, polling is not free of any obligation, as it presents a particular commitment towards the participant, even when residents initiate the poll.

Allowing different types of visualization to co-exist promotes engagement. Some visualization types, such as line graphs or scatterplots, or the combination of several data sets, are considered as complex, which inhibits engagement (Sprague and Tory, 2012). Our storylines included a range of visualization types and data ranging from percentile statistics to one-week historic data. Likewise, we learned how lay users like passers-by chose to engage with the visualizations that presented content in a simplified and bite-sized format. On the other hand, some passers-by were particularly interested in analyzing the statistical results, for instance to underpin their opinions with more or better objective evidence. Designers of public visualization should consider serving different types of data consumption, as it allows for a more varied audience engaged with the issue. Even when citizens might neglect more complex forms of data communication, we believe that public visualization supports familiarizing a wider and more representative audience with data, and spurs the general societal expectation that 'smart' public decisions should be based on transparent and verifiable forms of evidence.

#### 6.11.4. Resident and environment

The lack of overview on the content of the distributed public visualization and polling inhibits more collective forms of engagement by residents. Although we anticipated that residents would consult the displays of other participating peers – hereby creating unique opportunities of collaborative action – they rarely did, mainly because of time constraints. As a result, some residents had little inspiration to write an opinion or a polling question, also because they felt their efforts seemed not community-supported. In future work, designers could integrate a comprehensive overview of community efforts, such as the storylines of other residents, their opinions and polling questions, and potentially the polling results.

The daily presence of the researcher to update the content promotes engagement of residents. The researcher's presence functioned as a spark (Wouters, Downs, Harrop, Cox, Oliveira, Webber, Vetere and Vande Moere, 2016) for social interactions to occur between residents and non-participating neighbors. This phenomenon will potentially disappear with better, i.e. more ubiquitous, wireless infrastructure such as presented by current advancements in IoT. Future research could investigate how a proper interaction design might replicate this effect, such as by providing a unique visual or auditory experience during the update of the displays that can only be experienced by sharing the outside space.

#### 6.11.5. Resident and carrier

Residents are conscious of determining the ideal spots on their facade to catch attention of passers-by, yet some have issues with design tasks. Different design attitudes became apparent, as residents deliberately chose particular display arrangements to be more noticeable, or expressed the desire to customize the colors and textures of the casings of the displays. The semi-private space of a house façade is sensitive, in that residents feel aware that passers-by judge the outer appearance (Vande Moere, Tomitsch, Hoinkis, Trefz, Johansen and Jones, 2011). In that sense, the physical aspects of public displays could be co-created and be better adapted to particular architectural features or personal aesthetic preferences, which in turn would strengthen the authorship of the shown content. The physical design might also better articulate narrative structures, such as the order, context or importance of particular story elements.

#### 6.11.6. Resident and content

Real-time data proves not always to be the ideal, persuasive evidence to convey an environmental issue. For instance, air pollution might not be obvious depending on weather or traffic conditions. As a result, storylines that involve real-time data might not be particularly persuasive, for instance when they lack outliers, peaks or other apparent trends that tend to encourage people to inspect a public visualization (Claes and Vande Moere, 2017). As narrative visualizations cannot control the evolution of real-time data, they can still overcome this issue by conveying historical data that contrasts current events with other, more evoking, timeframes or similar locations.

The co-authoring process of the content causes residents to actively engage with the overall issue, and even discover new insights. By opinionating the storylines that were evidenced on data, residents were forced to reflect on different viewpoints and how these would be perceived by passers-by. Bottom-up public visualization system like DoS therefore not only encourages raising awareness of passers-by, yet seems to activate the ones that deploy the system more. As such, potential strategies might be devised that dynamically spread the hosting of the displays over a neighborhood, or opens up the content authoring over neighbors instead of only the hosting residents.

## 6.12. Conclusion

We presented the iterative design process of a distributed public visualization and polling system. The in-the-wild evaluation of this system revealed how polling promotes the discovery of data. Yet private characteristics of the location of public visualization inhibit participating in the poll. Overall, we have strong indications that public visualization on private locations inhibit engagement rather than promote, yet encourage reflection on the issue. Therefore, when local champions want to deploy public visualization to raise awareness on data-evidenced civic concerns, they should consider locating the public displays at public areas, to overcome the inhibiting factors.

# 7. Discussion

In this chapter, we discuss the three main contributions of this thesis: 1) a novel evaluation model for public visualization, 2) five public visualization demonstrators, and 3) nine design guidelines.

## 7.1. ERI model

We present ERI, a novel evaluation model to study the insight-generating capacities of public visualization. This contribution responds to RQ4, i.e. *How can insight generation caused by public visualization be evaluated in casual contexts?*

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### 7.1.1. Motivation

As embedded representations, such as public visualization, are increasingly deployed, there is a need for more effective evaluation methods that allow

1) to measure how visual representations are able to engage citizens in an insight-generation process, and
2) to learn how the surrounding environment influences these insights

(Willett, Jansen and Dragicevic, 2017). We present the Engagement-Reflection-Insight (ERI) model, which is based on two existing HCI engagement analysis models (Alt, Memarovic, Elhart, Bial, Schmidt, Langheinrich, Harboe, Huang and Scipioni, 2011; Sprague and Tory, 2012) and was iteratively developed throughout the last four case studies of this thesis.

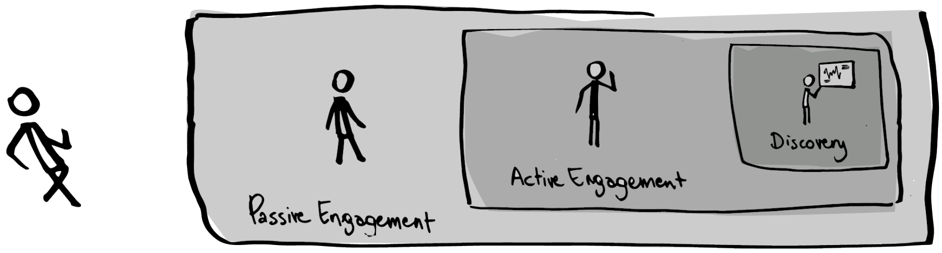


Figure 7.1 A passer-by (left) notices the public visualization (right) in the passive engagement stage, then walks towards the display while reading the content in the active engagement stage and touches the display to explore the visualization in the discovery stage.

### 7.1.2. PACD model

The Passive-Active-Discovery (PACD) model is deployed in the field of public displays (Memarovic, Langheinrich, Alt, Elhart, Hosio and Rubegni, 2012), and consists of:

- A passive engagement stage, which includes activities such as glancing at the public visualization or other people who are interacting with the public visualization;
- An active engagement stage, including reading the title or inspecting an outlier, or briefly interacting with the public visualization;
- A discovery stage, in which participants are inspecting the visualization without interaction, or they are interacting with the public visualization to submit input or explore output.

Video- or researcher observations are deployed to capture the activities. Then, these observations are analyzed and categorized according to the stages of PACD.

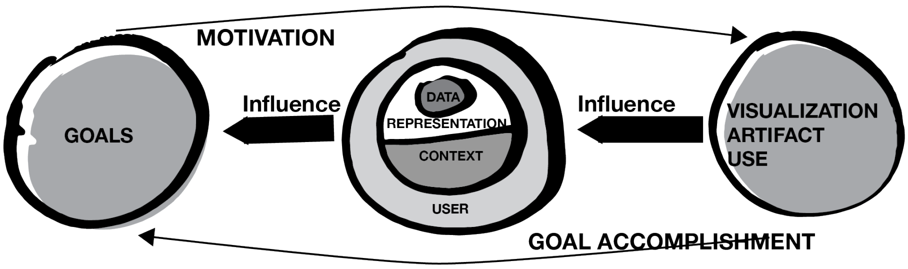


Figure 7.2 Simplified scheme of relations in the Promoter-Inhibitor-Motivation Model (PIMM). In the middle, the design factors of data, its representation, the context of interpretation and the experiences of the user, influence goal production. When this user interacts with the visualization (i.e. visualization artifact use), source factors are altered, which potentially leads to goal accomplishment.

### 7.1.3. PIMM model

The Promoter-Inhibitor-Motivation Model (PIMM) originates from the field of casual visualization and focuses on the goals and motivation of viewers to engage with data and visualization (Sprague and Tory, 2012). When viewers transit from passive to active engagement, they are aware a visualization exists without necessarily identifying what data or content is being represented. The transition from active engagement to discovery is characterized by the recognition of a visualization (either its content or the carrying artifact), which involves the motivation to accomplish the following goals:

- Intrinsic goals (e.g. finding personal relevancy in the topic, formulating a hypothesis) or
- Extrinsic goals (e.g. social pressure)

These motivations may promote engagement with visualization, or inhibit engagement, such as the social embarrassment we observed in *Data on Site* (Chapter 6). As shown in Figure 7.2, the design factors of data, representation and context influence the goals.

Semi-structured interviews are deployed to capture the viewer's goal of approaching and engaging with visualization, and the findings. PIMM supports the analysis of these interviews to identify the role of the design factors, in particular the role of context.

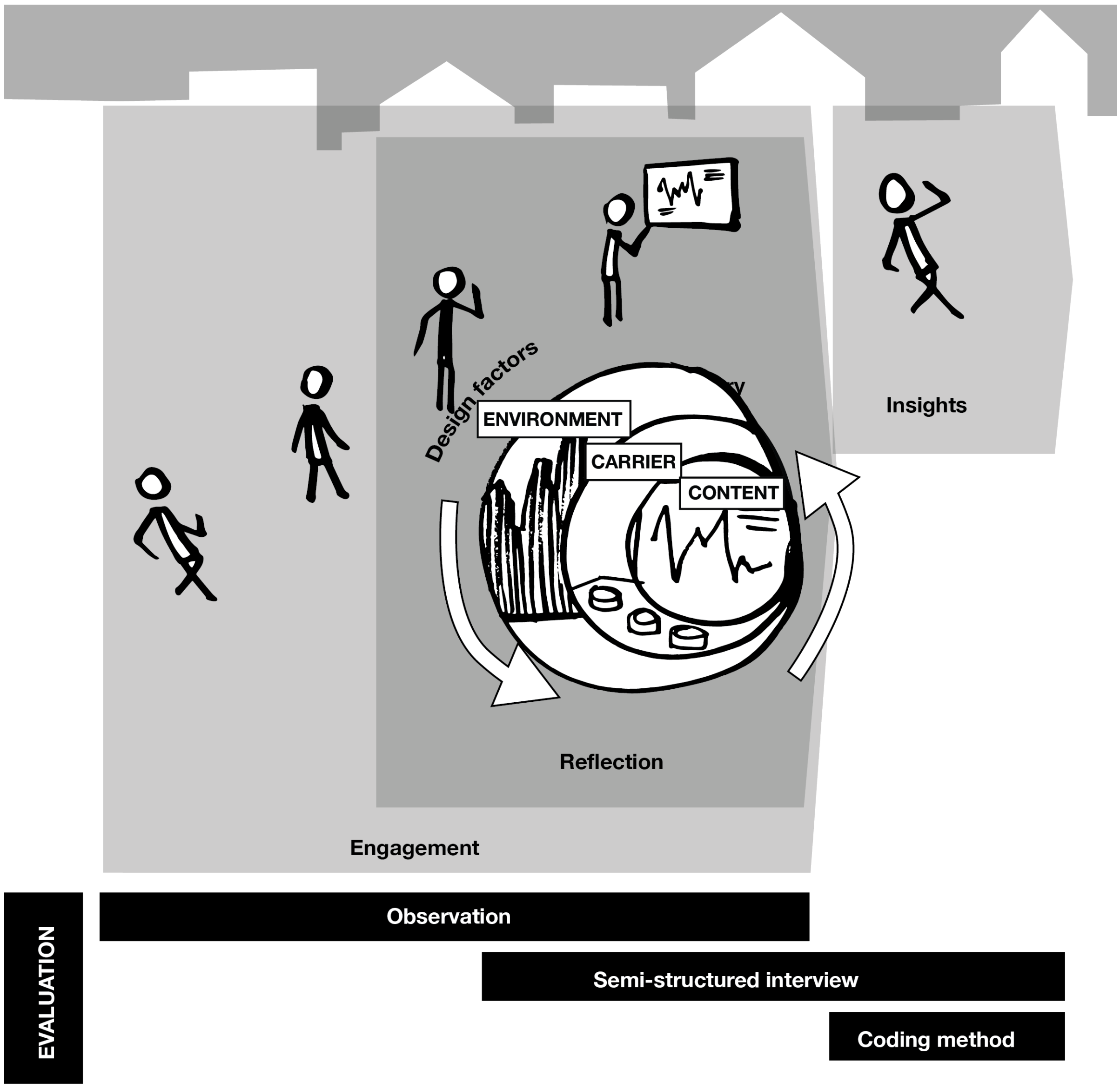


Figure 7.3 A passer-by (left) engages with public visualization in a passive and active way, discovers information while interacting and walks away with insights (right).

### 7.1.4. Approach

In all case studies, we implemented a prototype in-the-wild, at least for two days. A researcher present observed these prototypes. The notes of these observations were annotated and guided by the PACD model, which we applied for the first time in *Sight on Local Data* (Chapter 3). We continued to apply the model in *Bicycle Barometer, Narrative Visualization* and *Data on Site* (Chapter 4, 5 and 6).

When a passer-by engaged with the prototype, he or she was approached for a semi-structured interview to question their motivation and findings. Questions were formulated in an open-ended manner in order to encourage interviewees to describe their motivation and experience, and findings in detail. The questions targeting motivations were informed by PIMM, which we applied for the first time in *Narrative Visualization* (Chapter 5). PIMM allowed us to study the motivations to transit between the PACD engagement stages, caused by the public visualization. We further applied the combination of PIMM and PACD to analyze results of *Data on Site* (Chapter 6).

The second objective of these semi-structured interviews was to collect findings of interviewees. In Sight on Local Data, Bicycle Barometer, Narrative Visualization and Sight on Local Data (Chapter 3, 4, 5 and 6), we deployed the insight-reporting methodology of infovis to analyze the depth of these insights, which coding scaled from factual, over interpretational to personal insights (Saraiya, North and Duca, 2005).

### 7.1.5. Results

Findings[2] are also generated in the passive and active engagement stages, before actual discovery with public visualization takes place. In Narrative Visualization (chapter 5), a passer-by that did not interact with the public visualization, except for briefly reading the title (i.e. reported to read something about cycling) and glancing at the line charts (i.e. reported to notice outliers), reflected on the purpose of the visualization (i.e. reported to expect the visualization to present policy decisions on cycling). The surrounding environment (i.e. reported to expect information of the city council on that location) was thus reflected in the reported findings. We also learned this in Data on Site (Chapter 6). For instance, a passer-by reported to expect negative values for particle matters before the discovery stage (i.e. reported as motivation to inspect the content). This expectation was based on previous knowledge of the issue. Yet when actually inspecting the public visualization, this passer-by learned the values for that day were positive, causing the passer-by to further inspect for reasons to explain that trend. These examples demonstrate how reflection before the discovery stage influences the engagement and insight-generation process, which motivated us to highlight a separate phase for reflection in our merged model approach of PACD and PIMM.

[2] In Chapter 1, we defined the difference between finding and insight.

### 7.1.6. ERI model

As shown in Figure 7.3, the ERI model consists of three phases: 1) Engagement, 3) Insight-generation, 2) Reflection is nested in the overlap of those two phases. The three phases are discussed in the following.

#### 1) Engagement

Engagement comprises of all the actions a passer-by takes before and during interaction with public visualization. When a passer-by walks away from the public visualization, the engagement phase is ended. Actions include approaching (made obvious through glancing, walking towards, etc.), reading (made obvious through inspecting from closer-by for a couple of seconds), exploring (made obvious through interacting with the content) and – if possible – submitting content.

Actions are captured through observations.

#### 2) Reflection

During the engagement phase, a passer-by has expectations of the content, which are reflected in their goals. More specific, passers-by reflect upon these goals in relation to the three design factors, i.e. surrounding environment, carrier and content, causing passers-by to engage with the public visualization with a particular frame of mind. In turn, this frame of mind influences the type of insights. For these reasons, which are specific for public visualization, we highlight reflection as a separate stage, nested in the engagement process (see Figure 7.1).

Reflection is evaluated through semi-structured interviews that question motivations for approaching and interacting with public visualization.

#### 3) Insights

Insight-generation occurs during and after active engagement or discovery processes with public visualization. By defining this as a separate stage, we highlight the transition from discovering findings that are related to the presented topic to generating insights based on the presented data.

### 7.1.7. Future work

Already ten years ago, several calls were made to define methodologies to evaluate insight that is generated through infovis (Johnson, Moorhead, Munzner, Pfister, Rheingans and Yoo, 2006; North, 2006), and initial attempts to set up an insight-reporting methodology were made (Saraiya, North and Duca, 2005). Yet with the expansion of infovis towards implementation in physical settings (Willett, Jansen and Dragicevic, 2017), thereby targeting reflective behavior of a wide audience, a systematic approach to study these reflections might be more urgent. Our ERI model contributes to defining a methodological approach to study the generation of visualization insights, by capturing the motivation to interact with visualization, thereby highlighting these motivations and other contextual conditions in the coding process of the insight-reporting methodology. As such, this model could be applied in future HCI studies that aim for general reflection and insight-generation on data in semi-private settings, such as smart house data in the home (Houben, Golsteijn, Gallacher, Johnson, Bakker, Marquardt, Capra and Rogers, 2016) or wedding data at the event (Elsden, Durrant, Chatting and Kirk, 2017).

Furthermore, engagement in infovis is not yet clearly defined as it is a complex construct (Saket, Endert and Stasko, 2016; Hung and Parsons, 2017). The ERI model contributes to the definition (Boy, Detienne and Fekete, 2015) and preservation (Amini, Riche, Lee, Hurter and Irani, 2015) of engagement in infovis, particularly because the real-world, public setting allowed us to observe and interview users after their fully voluntary and opportunistic interaction with a visualization. Such qualitative interview data is hard to capture when visualization resides online. Indeed, the physical wandering behavior is not unlike that of online information 'flaneuring', i.e. seeking information randomly (Dork, Carpendale and Williamson, 2011), so that the analysis of how people engage with public visualization may well provide complementary understanding to how information seekers approach infovis online.

We believe our model can help capture the spatial and contextual aspects that affect users of interactive systems, and public visualization in particular, yet it is only one step towards a comprehensive model of engagement with public visualization. This model is based on findings of our five case studies that varied in content, carrier and environment, and time, participants and their mindsets. As such, its validity is limited to those specific contexts. Therefore, this model is not generative or prescriptive, yet helps designers to map the engagement process in order to better understand how content and carrier of visualization is connected to the environment. In general, ERI allowed us to learn that design aspects that can initially be studied from far (i.e. reading the main title, interpreting the location of placement, interpreting the material dimensions of public visualization) are crucial for continuation of the engagement process (i.e. promoter or inhibitor) and the generation of insights (i.e. questions arise).

## 7.2. Public visualization demonstrators

We developed five public visualization demonstrators. The design process of these demonstrates typically followed 4 phases: 1) identifying the issue, 2) design of the content, 3) prototyping, and 4) in-the-wild deployment.

### 7.2.1. Identifying local issues

As shown in Table 7-1 (below, in 'study'), the design process of *Street Infographics, Bicycle Barometer* and *Data on Site* departed from a real, data-driven issue that a local civic organization aimed to communicate to citizens. Because of the hyperlocal qualities of the issues, we also studied the context of deployment in this initial design phase, through observation and informal interviews on the streets.

### 7.2.2. Design of data and visual representation

As a result of the different issues our case studies addressed, we explored various data types, including real-time and static data, quantitative and qualitative data, and contributed and volunteered data. The varying issues and number of data sets required different types of visual representations, or combinations of visual representations, which also varied in complexity (see Table 7-1).

### 7.2.3. Prototyping

The design of interaction features was explored with both the research question and the local issue in mind. Each of the demonstrators was then part of an iterative design process; after an initial sketching phase, a physical demonstrator was made and presented to potential users. Based on their remarks, a second prototype was developed. In case of *Bicycle Barometer* and *Data on Site*, at least 3 prototypes were developed. The materials of these demonstrators varied according to the required type of engagement behavior of passer-by (e.g. supporting cyclists in *Bicycle Barometer*) and the researcher (e.g. light-weight to allow for set up by a single person in *Bicycle Barometer*).

The *Bicycle Barometer* reached beyond the prototyping stage, as it was further developed by Q-lite[3], a company in digital signage. We discussed the design of the construction with their product engineers, and supervised the development.

[3] http://www.q-lite.be/

### 7.2.4. In-the-wild deployment

Each demonstrator was evaluated in a real-world environment. At least one month in advance, we obtained permission of the city council to occupy public space for a particular time. Locations for deployment were chosen in relation to the issue and the spatial requirements of the demonstrator, and also more practical requirements, such as the vicinity of electrical sockets or internet connection. Because of the temporary qualities of the demonstrators of the *Sight on Local Data, Bicycle Barometer* (version 1) and *Narrative Visualization* demonstrators had to be removed and replaced on a daily basis during the course of deployment.

Participants were recruited i) on invitation In *Street Infographics*, *Bicycle Barometer* and *Data on Site*, i.e. in particular by knocking on their door, launching calls on Facebook or in specialized newsletters, or by personally approaching people via the network of the civic organization or our university, or ii) spontaneous, i.e. passers-by that encountered the demonstrators without pre-defined knowledge. For the video observations made in *Sight on Local Data,* we obtained permission of the privacy commission in Flanders. For the in-the-wild study in *Data on Site*, we received permission of the KU Leuven ethical commission.

Table 7-1 Overview of different characteristics of public visualization design, categorized according to three design factors interface, carrier and context.

| | | **Street Infographics** | **Sight on Local Data** | **Bicycle Barometer** | **Narrative Visualization** | **Data on Site** |
|---|---|---|---|---|---|---|
| Content | *Data* | Volunteered | Volunteered | Contributed, volunteered | Volunteered | Contributed, volunteered |
| Content | *Nr. of data sets* | 2 | 12 | 4 | 8 | 17 |
| Content | *Data source* | Hyperlocal | Local | Hyperlocal | Local | Hyperlocal |
| Content | *Representation type* | Matrix | Line charts | Bar chart<br>Line chart | Line charts | Matrix<br>Bar charts<br>Line charts |
| Content | *Representation complexity* | Medium-low | Medium | Mixed | Medium | Mixed |
| Content | *Presentation* | Non-narrative | Non-narrative | Non-narrative | Narrative | Narrative |
| Carrier | *Interaction technology* | / | Tangibles shaped as charts | Floor mat and button | Touch | 3 buttons |
| Carrier | *Purpose of interaction* | / | Consulting | Contributing & consulting | Consulting | Contributing |
| Carrier | *Output of interaction* | / | Filter and combine | Polling and exploring | Authoring story and filter | Polling |
| Carrier | *Output technology* | / | LCD display | LED display | LCD display | e-Ink display |
| Carrier | *Carrying artifact* | Street sign | Telescope installation | Tailor-made construction | / | 3D printed case & facade |
| Carrier | *Material* | Paper | Wood | Wood (v1)<br>Aluminum (v2) | Aluminum | Plastic |
| Carrier | *Location* | Distributed | Centralized | Centralized | Centralized | Distributed |
| Environment | *Environment* | Streets | Shopping street | Bicycle lane | Public library | (Shopping ) streets |
| Environment | *User activity* | Walking, Wandering | Walking, wandering, shopping | Cycling | Walking, wandering | Walking |
| Environment | *Space* | Public | Public and semi-public | Public | Semi-public | Public |
| Study | *Demand of* | City council | Flanders DC | Province of Vl. Brabant | Province of Vl. Brabant | City council and neighborhood committee |
| Study | *Target* | Preparing civic debate | Making data transparent | Making data transparent | Making data transparent | Preparing civic debate |
| Study | *Issue* | Student nuisance | / | Dangerous bicycle intersection | / | Local air pollution |
| Study | *Passers-by* | 299 | 461 | 247 | 1133 | 872 |
| Study | *Interviews* | 24 | 49 | 63 | 54 | 28 |
| Study | *Deployment time* | 6 days | 4 days | 6 days | 4 days | 20 days |

## 7.3. Design guidelines

We present design guidelines that support insight generation through public visualization. These guidelines are based on the design recommendations formulated in the different chapters (see Table 7-2). The guidelines provide an answer to our research questions. First, we will present general guidelines that answer our general research question:

> **(RQ0) How can the design of public visualization encourage citizens to generate insights in casual contexts?**

Second, we will present specific guidelines that respond to our sub research questions:

- *(RQ1) Does a narrative approach of public visualization affect engagement and insight generation?*
- *(RQ2) How the use of physical interaction elements impact engagement and insight generation with public visualization?*
- *(RQ3) How do specific contextual conditions of public visualization affect engagement and insight generation?*
- *(RQ4) How can insight generation caused by public visualization be evaluated in casual contexts?*

Table 7-2 Overview of the different case studies and their respective design recommendations.

<table>
<tr><th>Chapter</th><th>Design recommendations</th></tr>
<tr><td>2. Street Infographics</td><td>- Six design characteristics for public visualization (RQ0, RQ3);<br>2.1 Local and Social;<br>2.2 Aesthetic and Medium<br>2.3 Insightful and Persuasive<br>2.4 Contextual<br>2.5 Opportunistic<br>2.6 Trustworthy</td></tr>
<tr><td rowspan="2">3. Sight on Local Data</td><td>- Identification of the role of physical design characteristics in four design recommendations (RQ2):<br>3.1 Affords different types of engagement behavior;<br>3.2 Shifts extrinsic to intrinsic user goals;<br>3.3 Enforces the public character of interaction;<br>3.4 Encourages social interaction;</td></tr>
<tr><td>- Novel evaluation methodology of controlling in-the-wild studies (RQ4)</td></tr>
<tr><td rowspan="2">4. Bicycle Barometer</td><td>- Identification of how targeting a specific civic audience encourages engagement with public visualization, in eight design recommendations for cyclist-specific interaction with a public display (RQ3);<br>4.1.1 User-specific interactive and physical features encourage passive engagement;<br>4.1.2 Teasers guide into active engagement;<br>4.1.3 Balance novel and familiar interactive features to overcome usability issues;<br>4.1.4 User-specific interactive features lowers engagement barriers;<br>4.1.5 Content motivates the continuation from passive to active engagement;<br>4.1.6 The relevance of content is weighed to the environment<br>4.1.7 The physical actions caused by interactive features afford sense-making<br>4.1.8 Social interaction spaces should be included in the physical design.</td></tr>
<tr><td>- Identification of how material dimensions affect engagement with public visualization (RQ2);<br>4.2.1 Impermanent dimensions influence appropriation, perception of ownership and participation urgency;<br>4.2.2 Imperfect dimensions impact expectations and reflections;<br>4.2.3 Incomplete dimensions imply an emotional relation with researcher.</td></tr>
<tr><td>5. Narrative Visualization</td><td>- Identification of the role of (RQ4):<br>5.1 Narrative design strategies on public visualization (RQ1), in particular on:<br>- Comprehension rate;<br>- Personal reflection;<br>- Authorship.<br>5.2 The surrounding environment on public visualization in general (RQ3):<br>Social collaboration;</td></tr>
</table>

| | |
|---|---|
| | Perception; |
| *6. Data on Site* | Identification of the role of three design factors; content, carrier and environments (RQ0, RQ1, RQ2, RQ3, RQ4):<br>6.1 Ambient dimensions of public visualization allow for long-term engagement;<br>6.2 Physical distribution allows for an extended public display landing zone;<br>6.3 Social distribution allows for rich interpretations;<br>6.4 Social desires promote or inhibit engagement and insight discovery;<br>6.5 Setting user goals encourages insight discovery;<br>6.6 Co-authoring allows for anticipation on the actual, local situation;<br>6.7 Content distribution should be explored as a narrative design strategy. |

### 7.3.1. (RQ0) General research question

In our research question, citizens are framed as target audience. Citizens are a diverse group of people with varying characteristics and roles. In the following guidelines, we discuss strategies to engage this wide audience with data.

1. Passive engagement with public visualization familiarizes passers-by with visual representations.

*This guideline is based on design recommendation 6.1 (see* Table 7-2*).*

Narrative design strategies can guide citizens to make sense of the visual representation, while providing several scales of visualization complexities in public visualization allows to gradually reveal complexity. These strategies focus on active engagement. We argue that the presence of visual representations in public environments - in its ambient state, without further engagement at that time- is a means to encounter data and visual representations on a daily basis, thereby familiarizing passers-by with its presence in a passive way. Public visualization also implies that 'something' is being measured at that location, that 'this something' can be visualized, and lessons can be drawn from it.

Visualization literacy is getting increased attention (Boy, Rensink, Bertini and Fekete, 2014), focusing on teaching non-experts the ability to read visual representations. This design guideline contributes to the familiarization of a wide audience with visual representations, which might be considered as a first step towards active engagement with data.

2. Targeting a specific audience encourages active engagement with public visualization by that audience.

*This guideline is directly derived from design recommendations 2.1, 2.4, 4.1.1 and 4.1.4 (see* Table 7-2*).*

Public visualization can be designed for a specific audience by combining or focusing the specificity of the design on one of these levels. This design approach ensures the public visualization is relevant for the target audience, which encourages engagement.

Overcoming difficulties of public visualization (e.g. visualization complexity, learning curve for interaction)

A specific audience can be addressed through

1) Hyperlocal content: In *Street Infographics* (Chapter 2) and *Data on Site* (Chapter 6), we presented hyperlocal issues. As a result, the content was relevant for the residents, which encouraged them to engage in an active way with the public visualization.
2) Specific physical features: In *Bicycle Barometer* (Chapter 4), we learned how the bicycle-specific appearance of the public visualization carrier was key motivation for a specific audience to cast their vote on a topic that is related to that specific audience, and explore other relevant data sets.
3) Environment: In *Street Infographics* (Chapter 2), we learned that the location of the public visualization implies the target audience of the public visualization. This finding was also observed in *Data on Site* (Chapter 6).

This finding is relevant for studies on public displays, as they are often executed independent from contextual influences, such as hyperlocal content or specific carrier design (Wouters, Claes and Vande Moere, 2015). However, our finding demonstrates how efforts towards designing for a specific context, is rewarded with more engagement.

3. Allowing passers-by to express their opinion via public visualization encourages discovery of insights.

*This guideline builds upon a design recommendation 6.5 (see* Table 7-2*).*

The co-design workshop in *Bicycle Barometer* (Chapter 4) revealed that one of the main design requirements of public visualization is to facilitate polling on the assigned issues. Also in the co-design workshops presented in *Data on Site* (Chapter 6), polling features were expressed as a design requirement of public visualization in order to lure passers-by into active engagement. Besides the engaging aspect, the ability to express an opinion also motivated citizens to discover related data sets*; i) before,* as a motivation to check if their opinion was grounded (*Bicycle Barometer*) *or ii) after,* as a motivation to express an informed vote (*Data on Site*). As such, polling features also encourage the discovery of insights. Thus, when designers of public visualization integrate polling features on a particular issue, they should consider the opportunity to present related data sets to allow passers-by to acquire a better understanding of the issue.

Several HCI studies have explored polling as a strategy to engage citizens with a civic issue, in which the public visualization is limited to the graphical representation of the polling results (e.g. (Valkanova, Walter, Vande Moere and Müller, 2014; Koeman, Kalnikait and Rogers, 2015; Taylor, Lindley, Regan, Sweeney, Vlachokyriakos, Grainger and Lingel, 2015). In our case studies, we exploit polling as a design strategy to engage people with other related data sets of the issue presented in the public visualization.

### 7.3.2. (RQ1) Narrative approach for public visualization

4. Applying narrative design strategies to public visualization support citizens to discover insights.

*This guideline is directly derived from design recommendation 5.1 (see* Table 7-2*).*

In *Narrative Visualization* (Chapter 5), textual annotations were set up to guide passers-by to interpret a complex representation, such as line graphs. These annotations were structured by a narrative, which we found to serve as a tutorial to learn how to inspect a graph, and to encourage citizens to find 'proof' for the claims made in the annotations. In *Data on Site* (Chapter 6), we applied narrative strategies in the form of textual annotations that follow a particular narrative, and in the physical distribution of several narratives. Here, the narratives supported citizens to find personal relevance in the data. Designers of public visualization should incorporate textual annotations that reveal insights of the visual representation. When these annotations are connected through a narrative, citizens are supported to appropriate data sets, which leads to the discovery of insights.

This finding is also relevant for infovis research in general. The deployment of narratives to engage users with visualization has been disputed, mostly because of the lack of evaluation methods for engagement with infovis (Boy, Detienne and Fekete, 2015). Here, engagement is measured as the time a user spends with the visualization. In *Narrative Visualization* (Chapter 5), we observed that narratives do not cause longer engagement times. Yet, narratives do elicit more active ways of data engagement, such as interpreting the relationship of data and the environment or the perceived author, resulting in more varied types of insights, which connects to the goal of casual visualization (Pousman, Stasko and Mateas, 2007).

### 7.3.3. (RQ2) Physical interaction elements of public visualization

5. Interacting with public visualization in a physical way elongates the insight discovery process.

*This guideline is based on the design recommendation 3.1, 3.2 and 4.1.7 (see* Table 7-2*).*

Physical interaction requires citizens to perform physical actions to discover (more) data, providing time to make sense of the data. Spatial dimensions, as explored in *Street Infographics* (Chapter 2) and *Data on Site* (Chapter 6) are an integral part of public space and thus inherently part of public visualization. In *Sight on Local Data* (Chapter 3), we studied the role of tangible interaction, in which we also discovered how the spatial features of one specific condition enticed participants to move around the public visualization, resulting in more insights. Further, in *Bicycle Barometer* (Chapter 4), the participating cyclists and pedestrians were required to take an action in order to vote and explore data, which elongated the engagement process. We recommend designers of public visualizations to exploit the physical interaction possibilities provided by the public visualization carrier, and its environment.

In the field of public displays, physical interaction is typically studied in semi-public contexts, because technology is not yet sufficiently robust for outdoor deployments (Damala, van der Vaart, Clarke, Hornecker, Avram, Kockelkorn and Ruthven, 2016; Ullmer, Tregre and McClay, 2017)). Our findings demonstrate how physical interaction can overcomes interaction blindness in a crowded, public environment (Ojala, Kukka, Lindén, Heikkinen, Jurmu, Hosio and Kruger, 2010), while engaging passers-by to actively discover content.

### 7.3.4. (RQ3) Contextual conditions of public visualization

6. The physical environment surrounding public visualization affects engagement and discovered insights.

*This guideline is based on design recommendations of 4.1.6, 6.3 and 6.4 (see* Table 7-2*).*

Data is never 'raw' or objective, as there is always some kind of decision making process behind its selection and presentation (Elsden, Mellor, Olivier, Wheldon, Kirk and Comber, 2016). In semi-public spaces, such as a library, the perceived owner of the surrounding environment is considered as author, which caused passers-by to speculate on the purpose of *Narrative Visualization* (chapter 5). However, in *Street Infographics* (Chapter 2), we learned that passers-by in a public environment recognize public visualizations to serve a variety of purposes, including political, social, commercial, guerilla, depending on the understanding of the socio-cultural aspects of the environment by the passer-by. In *Narrative Visualization* and *Data on Site* (Chapter 5 and 6), we observed how the speculations on these purposes appeared in the reported insights. The environment thus plays a crucial role in the interpretation of data. Designers should therefore carefully study the environment in which public visualization will be located, and deploy contextual clues, such as the deployment of identity-bearing street signs (Chapter 2) or an issue that is known by locals (Chapter 6) in the design. Concretely, designers can map the physical, as well as the social and cultural characteristics of the location and connect it with the public visualization.

Considering space (defined as 'place is the social and cultural construct within a physical space) as external factor in public display design has only been identified recently (Mäkelä, Sharma, Hakulinen, Heimonen and Turunen, 2017). Yet our findings demonstrate that mapping the invisible, social dimensions of an environment can reveal connection points for the content design, which should be considered in the design next to the physical dimensions of sight lines or interaction spaces (Fischer and Hornecker, 2012).

## 7.4. Future work

Here we present two 'future' design guidelines that are based on our tacit knowledge, yet are not empirically proven. This section also highlights two emerging research questions that were not the focus of this work.

### 7.4.1. Future design guidelines

(7) Material dimensions of the carrier influence insight-generation

*This guideline builds upon design recommendation 4.2.2*

The study in Chapter 4.2 showed how material dimensions affect engagement and expectations of the general purpose. Yet we did not empirically proof that the expectations caused by the material dimensions influenced reported insights. Throughout our case studies we explored different material dimensions, ranging from looking complete and perfect (i.e. *Data on Site, Narrative Visualization*) to incomplete and imperfect (i.e. *Street Infographics, Sight on Local Data*). Our findings in these case studies indicate that material dimensions of the public visualization carrier also contribute to the insight-generation process, similar to the role of the environment in 7.3.4. However, future research is required to evaluate this in an empirical way, for instance by a comparitive study with different material finishes in a controlled in-the-wild setting.

(8) Providing several types of representations motivate passers-by to actively engage with public visualization.

*This guideline is based on general observations made in Bicycle Barometer and Data on Site.*

Public visualization aims to reach a wide audience with data, including people with low visualization literacy skills. In *Sight on Local Data*, *Narrative Visualization* and *Data on Site* (Chapter 3, 5 and 6), we learned how passers-by were inhibited to engage with a public visualization because of the perceived representational complexity. In contrast, other passers-by were motivated to engage because of the presence of more complex representations. We deployed two design strategies to allow different scales of complexity in the design:

1) In *Bicycle Barometer* (Chapter 4), the visualization was a sequence of three visualization types, gradually exposing the participating passer-by to more difficult visualization types.
2) In *Data on Site* (Chapter 6), the design combined different types of representations, varying from easy to complex.

These two strategies allowed different types of data consumption, from fast 'on-the-go' information to deeper inspection. We have indications that these strategies caused passers-by to pick the level they prefer at that time, which motivated them to engage with public visualization. Currently, however, we lack empirical data.

HCI studies on casual visualization deploy relatively easy representations in order to engage a wide audience, e.g. a bar chart that reveals temparture values over time at home (Costanza, Bedwell, Jewell, Colley and Rodden, 2016)). However, our case studies, provide indications that the representational complexity can also motivate people to engage with visualization, which should be studied in future research.

### 7.4.2. Limitations

As the case studies varied in the issues it addressed, the visualization formats, the material dimensions of the carrier, and the environment, the contributions of this thesis are difficult to generalize and are therefore limited. However, as we have discussed the context of the study in each chapter in a transparent way, we believe our findings will support designers in their understanding to set up public visualization projects.

This thesis provided one of the first explorations of the possible benefits of public visualization in civic participation. As such, we encountered several limitations, such as the limited case study duration (addressed in 7.3.2.1), the impact on civic participation (in 7.3.2.2) and the ever-changing role of technology (in 7.3.2.3).

#### 1.1.1.1. Deploying public visualization on the long-term

The presented case studies are deployed during a relatively short period of time – ranging from 4 days to 20 days. As such, how citizens engage and discover insights with public visualization over a longer period of time is still an open question. Based on our findings in *Data on Site* (Chapter 6), we assume that long-term deployments will trigger personal insights with passers-by as they more regularly encounter the public visualization.

One of the design strategies to encourage long-term deployment might be public polling, for which we found indications in *Bicycle Barometer* and *Data on Site* (Chapter 4 and 6). Future research should however look into more durable polling processes as current polling strategies support misuse because of the lack of identification (e.g. one can express a vote several times), which inhibits passers-by to engage when returning.  Such issues might be avoided when passers-by are able to input some basic demographic information.

#### 1.1.1.2. Design strategies for action

Our research focused on the design of public visualization to generate insights. Yet ultimately, some public visualizations aims to elicit civic participation, which requires some action taking. Therefore, Future research on public visualization might be inspired by strategies for behavior change, such as gamification, which proved motivational for changing behavior in the home with infovis (e.g. (Foster, Lawson, Blythe and Cairns, 2010; Micheel, Novak, Fraternali, Baroffio, Castelletti and Rizzoli, 2015)) or with public displays in urban contexts (e.g. (Laureyssens, Coenen, Claeys, Mechant, Criel and Vande Moere, 2014)). We question how these and other design strategies can be implemented in public visualization to trigger behavior change, and how a community can benefit from such strategies in particular. Long-term deployments (i.e. more than 1 month), will also allow evaluating the potential impact on behavior.

#### 7.4.3. Transferring design strategies to different technologies

The work in this thesis presented a variety of existing (e.g. touch display in Chapter 5, LED display in Chapter 4) and emerging (e.g. physicalizations in Chapter 3) situated technologies. However, technology is in constant flux. Our findings are also relevant for technologies, such as augmented reality applications that aim to present visualizations in the public environment, as the role of the surrounding environment and content remain similar. Future research in augmented reality should further investigate if embedding visualizations through augmented reality in public space results in different design strategies than the situated visualizations of our studies.

## 7.5. Concluding remarks

In this thesis, we explored how to design public visualization for encouraging engagement and insight generation in casual contexts. This research resulted in three main contributions, including 1) nine design guidelines, 2) an evaluation model that was tested in various contexts and 3) five public visualization demonstrators.

We are proud that two of our public visualization demonstrators have been deployed outside the research context. The Bicycle Barometer is further developed by Q-lite, a digital signage company, and is currently property of the province of Vlaams Brabant in Belgium. Recently, we received requests to deploy our Data on Site toolkit for civic projects in and outside Belgium. These two examples demonstrate that there is a need for public visualization products in the field.

We also demonstrated how our work on public visualization brings novel design strategies that consider narrative aspects, polling features and contextual influences, and an Engagement-Reflection-Insight evaluation model forward for the field of infovis in general. Also, designers of public displays can benefit from our design guidelines. In extent, we believe this work proves how different fields can learn from each other.

The design guidelines highlighted how several aspects of the context, including the role of content, carrier and environment affect engagement and insight generation, and exemplified their application. Furthermore, our case studies touched upon the potential of public visualization to elicit social discussion and collaboration, and to trigger civic engagement. Overall, public visualization promises to engage a wide civic audience with data. This thesis demonstrates how making data relevant and approachable for a wide audience encourages the discovery of insights in the casual context of public space.

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# A. Appendix

The following publication was a non-archived workshop publication of the Infovis'14 conference:

Claes, Sandy and Vande Moere, Andrew. "What public visualization can learn from street art." In Proceedings of the IEEE VIS Arts Program (VISAP), pages 51–55, Paris, France, November 2014.

A recuded version of this publication was published in Leonardo Journal in 2017:

Claes, Sandy, and Vande Moere, Andrew. "What public visualization can learn from street art." Leonardo (2017) MIT press.

## Personal reflection

*After the Street Infographics case study in Leuven in 2013, we set up a second case study in the Antwerp North area. This study aimed to compare three different contexts: one public visualization (i.e. a sunburst that plotted 9 data characteristics of the neighborhood) that is displayed on three different public display technologies (i.e. guerilla projection, a public display inside a public building, a public display facing the street) in three different neighborhoods during a two day set up. We aimed to compare insights. However, results of this case study were limited: only few passers-by noticed the public displays in the street, the visualization was too time-consuming for public space, insights were limited. This case study however was a learning experience, which helped me to decide on a focus for the following studies.*

*This case study is thus not included as a separate chapter in this thesis. Some of the results (in particular, the findings on the guerilla projection) however were juxtaposed to two other case studies, i.e. Street Infographics (Chapter 2) and Sight on Local Data (Chapter 3). I analyzed how these different case studies deployed visual representations in relation to the public environment by drawing upon rhetoric strategies of street art.*

*With support of Andrew Vande Moere, I authored the resulting publication. As this was an early piece of work, we discussed the goal of public visualization to present 'objective' data, which we later - throughout this PhD trajectory – learned that it never would be.*


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Groen
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## Abstract

*As public visualization is receiving more attention - in academic research as well as in everyday practice - we need to consider the physical environment as an important intrinsic component of its design. We propose that one should not disconnect a public visualization from the context in which it is read, as its immediate environment carries various meanings that influence its perception and interpretation. As the concept of street art also employs invisible meanings that are present in the environment in order to convey a message, it can act as a valuable resource for public visualization designers. As such, we will discuss four rhetoric strategies in order to demonstrate how street art practices succeed in relating to their environment, and how this relationship is able to trigger critical reflection. Departing from three public visualization case studies - which are inspired by street art - we discuss how they influence the appeal, the engagement and the sense-making process. For each of these rhetoric strategies, we describe design guidelines in order to help designers of public visualizations exploit communicational codes and meanings that are present in the environment.*

## Introduction

In recent years, concepts of information visualization have been used for other than strictly analytical purposes (Pousman, Stasko and Mateas, 2007), as 'casual' types of visualization aim to raise awareness, and encourage users to reflect upon the visualized issue (Pousman, Stasko and Mateas, 2007). To serve this purpose, casual infovis tends to borrow techniques from the arts in order to evoke curiosity, puzzlement, or even frustration, as well as to establish aesthetically pleasing designs. Even just the act of making data publicly available through its visualization, can allow social discussion and engage people to reflect on relevant insights (Button, 2008). Research efforts in public visualization demonstrate how infovis techniques can be exploited outside of work-related contexts, such as in public spaces (Vande Moere and Hill, 2012). While they become more common in everyday life, public visualizations are not limited to online media, but can range from physical sculptures or wearable objects (Khot, Lee, Hjorth and Mueller, 2014), over ambient displays for the domestic context (Rodgers and Bartram, 2011), to large, public screens (Behrens, Valkanova and Brumby). Currently, the design of public visualization tends to focus on the intrinsic characteristics of its graphical representation, and neglects the role of eventual extrinsic qualities, e.g. the environment in which it has been situated. Therefore, this paper investigates the need to consider the environment as an intrinsic component of public visualization, which is analyzed and discussed through the lens of *street art*.

## Public Visualization

Early indications exist that public visualization can engage a broad audience in interpreting complex information (Valkanova, Walter, Vande Moere and Müller, 2014), raise awareness on local concerns (Valkanova, Jorda, Tomitsch and Vande Moere, 2013), and add valuable, situated meanings to locally relevant information (Claes and Vande Moere, 2013). The immediate environment of a public visualization is often exploited as an opportunistic medium to reach the wide variety of users for which the information is intended, e.g. by means of house-attached data dashboards (Vande Moere, Tomitsch, Hoinkis, Trefz, Johansen and Jones, 2011) or by interactive projections (Valkanova, Jorda, Tomitsch and Vande Moere, 2013; Valkanova, Walter, Vande Moere and Müller, 2014). Even the street itself has been used as an information display medium, e.g. by drawing on asphalt (Bird and Rogers, 2010; Koeman, Kalnikaite, Rogers and Bird, 2014), or by attaching visualizations to existing urban furniture such as street signs (Claes and Vande Moere, 2013). Notably, in these particular projects, the environment adds valuable contextual meaning to interpreting the visualization, such as its situatedness to a specific street or neighborhood. This way, everyday environments are exploited as a rich, interpretable communication medium for making sense of a visualization for a broad, multicultural audience (Vande Moere and Hill, 2012). However, closer investigation is still required in how a surrounding environment can enrich a visualization in a meaningful, usable and valuable way, how this affects its general appeal, and augments the awareness or comprehensibility of a visualized issue.

In this appendix, we will discuss four rhetoric strategies as ways to potentially understand how the everyday environment can be exploited in influencing the interpretation of visualizations in the public. We will base these strategies on seven rhetorical practices which were theorized in research on street art (Borghini, Visconti, Anderson and Sherry, 2010), apply them to three of our own public visualizations and convert them to design guidelines. More specifically, the strategies address how the visual appearance relates to the surrounding environment, and what these relations succeed in communicating to an audience. A first strategy, i.e. *information access* points out how to reach attention of a broad audience in an everyday environment. Secondly, we discuss *playfulness* as a rhetoric strategy to raise audience curiosity, which thus potentially influences the general interest in a public visualization. Thirdly, the *manipulation of existing meanings* is a strategy to encourage people to interpret the information in relation to the environment. Lastly, the strategy *ambiguous signs of authorship* aspires to entice passers-by to reflect on the information shown, including its intentions. Consequently, all mentioned strategies aim to unravel the rich and still largely untapped interplay between a public visualization, its environment, and its 'users'.

### Street Art

The arts have already studied how media can be related to the surrounding environment, and how this affects public engagement. *Public art* in particular is generally created for installment in the public domain, as it pushes art outside of the traditional museum in order to become accessible to a broader audience. However, some critics accuse public art to be inaccessible, as it is not sufficient to be present in the public domain to be able to reach everyone (Young and Young, 2013). Public art can be hard to understand, and is therefore considered to be elitist (Young and Young, 2013). On the other hand, there exist a few public art movements - such as *street art* – that seem successful in bringing art to those people who would not normally encounter or experience it, while still being commonly understandable and enjoyable.


Figure 8.2 Street Infographics: one of the street signs with a visualization attached to it (Claes and Vande Moere, 2013).

Street art is an all-encompassing art form that is generally situated against an urban backdrop, and has grown directly from the *graffiti revolution* (Schwartzman, 1985). This means that – unlike graffiti – street art can hold various and different media types, such as stickers, posters, sculptures, performances, video projection and more. Typically, street artists tend to question the existing urban environment through its own language, and do so by installing temporary, spontaneous and situated interventions (Schwartzman, 1985). Inspired by *art activism*, street art interventions deploy the practice of *disruptive aesthetic* to attempt to unsettle existing political conditions, shared meanings and personal values, and often replace them with new ones (Markussen, 2013). For instance, in the urban intervention *Taking back to the street*, guerrilla artist and architect Cirugeda transformed trash containers into places for social interaction (Santiago, 2005). This way, citizens are allowed to create temporary public places whenever they want, without needing permission of the city council. Through its disruptive approach, street art aims to communicate directly with the public at large about socially relevant themes (Young and Young, 2013).

## Visualization versus Street Art

We propose that public visualization can be considered as the information visualization equivalent of street art versus traditional art, as they both distinguish themselves from an elite group of expert 'users', and both aim to reach a large, lay audience by being easy-to-understand, creating awareness and finding subjective emotional connotations with the information shown.

Obviously there are also differences; street art is driven by delivering a strong activist message, while public visualization aims to communicate data in a more impartial, objective and transparent way. It can be questioned however, if an impartial visualization can actually exist in public space, as any public manifestation of information can potentially be interpreted as a political act with some deliberate message (Claes and Vande Moere, 2013). Therefore, since visualization is increasingly becoming concerned with communicating social issues, visualization design should follow a more critical approach (Dörk, Feng, Collins and Carpendale, 2013). Furthermore, public visualization has not yet fully exploited the possibilities of using space and time as a medium. Therefore, this paper aims to explore how public visualization can better deploy the surrounding context through applying proven street art practices. Notably, learning from street art is not only applicable to urban (outdoor) environments, but could also be applied in broader and semi-public settings, such as musea, hospitals, city halls etc.

Specifically, we propose that the qualities of street art for public visualization are fourfold: (1) temporality, the transient appearance encourages people to explore the information then and there; (2) the ability to be located anywhere, provides the chance for the information to be locally and timely relevant; (3) spontaneity allows designers to intervene when specific issues are trending; and (4) altering the urban condition is known as a way to promote change (Markussen, 2013). We start by describing three of our own public visualization case studies that are all designed to intervene in the urban environment yet differ in terms of display media. All three visualizations were inspired by forms of street art rhetoric, which we will be discussed in Section 4, in terms of how our design choices intended to influence the appeal and interpretation of each visualization.


Figure 8.3 Projection bombing a neighborhood with visualization.

## Public Visualizations Cases Inspired by Street Art

### Street Infographics

In our public visualization *Street Infographics* (Claes and Vande Moere, 2013), we attached casual infovis boards to existing-street signs in a neighbourhood of Leuven, a mid-size city in Belgium. Here, the planning of a student housing complex provoked local concerns about the perceived unequal distribution between students, foreigners and permanent residents. Our goal was to inform residents of the actual situation of the socio-demographic composition. Therefore, we collected socio-demographic data of four specific streets, and visualized two data dimensions, i.e. the number of permanent residents and whether they were native. We distributed these data dimensions of the inhabitants of the street by means of categorizing 100 infographic-like icons (Figure 8.2). The graphic design of the visualization mimics the characteristics of a street sign in terms of color scheme, font choice and physical size. The actual data source was explicitly stated on the back of each sign.

By attaching visualizations to existing street signs, we subtly disrupted the everyday environment. While the visualization did not openly specify what location the data represented, its attachment to an existing street sign implied it to be information of that particular street. We deployed the visualization in four adjacent streets so that a third data dimension, i.e. the physical location, became available for passers-by who then had to explore the immediate environment for other signs in order to make data-driven comparisons.

### Projection bombing with visualization

In the second case study, we used a mobile video projection to 'bomb' different (urban) surfaces (see Figure 8.3). The data was based on a top five of issues that were trending in that certain neighborhood, according to a local survey in 2012 (Wynants, 2012). The overall goals of the intervention were to inform residents on the actual situation on several of the trending issues, to encourage them to reflect on the concerns, and to trigger social discussions in the neighbourhood. The data was collected from the local government (Antwerp, 2014) and visualized it as a star graph with 9 data dimensions, i.e. income, green area, health, migration, foreign born citizens, illegal dumping, amount of retail, contact with neighbours, leisure time

Figure 8.4 Two passers-by interacting with Sight on Local Data, inserting a Plexiglas plate with one dataset in the telescope.

and average age, which each was depicted as a distinct starburst graphic. The main visualization revealed several statistics of the local neighbourhood. This representation was contrasted by 8 smaller star graphs, each representing the same data for 8 nearby neighbourhoods of the same city. Three notable qualitative quotes of locals concerning one of the issues were shown to illustrate the local relevance of the data shown, e.g. "*This area might become to expensive for the common man*". The starburst visualization and the quotes were alternated by use of animated transitions, while the data source was clearly visible on the projection.

We used a mobile projector unit powered by means of a car battery, a car, a Raspberry Pi and a projector. The projection was particularly noticeable because of its approximate 3 by 3 meters physical size, and its non-trivial placement in the urban environment. We never announced when and where we would deploy a projection, and were sometimes present in multiple areas during a single evening. We projected on an abandoned factory, which is surrounded by café's and restaurants in the middle of the neighborhood. In a couple of months, this factory will be demolished, raising concerns with the locals about the new destination of this space. For those who were aware of this issue, the visualization seemed to engage with this concern, as some data dimensions dealt with opportunities for redevelopment, i.e. the little amount of green area and the unequal distribution of income. However, the visualization was always comprehensible, relevant and meaningful without local knowledge of this issue.

### Sight on Local Data

In a third case study, we designed a street art installation for the city of Leuven, Belgium, which we installed during a one-day trial run (Figure 8.4). Here, we did not depart from an existing local issue, as we wanted to explore what citizens were interested in through offering them a range of datasets. The general purpose of our design was to allow citizens to explore their city from a data-centric perspective, and encourage them to find meaningful connections across the data and statistics shown.

The physical appearance of this installation was reminiscent of a preliminary prototype; it did not look polished, but rather accentuated the typical bottom-up, DIY character of a temporary intervention. Its physical design resembled an urban telescope, which sufficiently familiar yet strange to entice passers-by to look through. The exterior of the installation was 1.80 meters high, 0.30 meters wide and 0.60 meters deep. Within the installation, people were invited to explore ten different datasets, such as birth rate, number of inhabitants, unemployment rate, people receiving benefits, disadvantaged people, number of parks, number of waste, income, energy use, and $CO_2$ emissions. We generated a time series line chart for each dataset, ranging from 2003 until 2011, which were normalized so they could be accurately compared. The graph lines were engraved on transparent Plexiglas (30 x 30 cm) plates. Each plate stated the title of its dataset and its information source. The telescope itself featured 3 slots, which allowed users to insert plates, look through the telescope with the inserted transparent plates, and subsequently compare a maximum of 3 datasets. None of the visualizations stated where the data originated from, which resulted in some ambiguous reflections (e.g. *is it data about the country in general, the province or the city?*). However, the obvious telescope metaphor encouraged passers-by to further interpret the environmental context and connect the visualization to the environment it was situated in.

## Rhetoric Strategies

The following rhetoric strategies are based on existing research on street art rhetoric (Borghini, Visconti, Anderson and Sherry, 2010). By applying them to our own case studies, we aim to formulate novel rhetoric strategies for public visualization, and reflect on how visualization designers could consider more creatively the role of the physical environment.

### Information access

The rhetoric strategy of information access indicates the difference between street art and contemporary art, as street artists renounce artistic sacralisation to allow freedom in the search for more powerful communicational codes or metaphors (Borghini, Visconti, Anderson and Sherry, 2010). Street artists want to reach 'everyone' and accomplish that in different ways; i) *replicability*, which increases the chances of exposure and retention; ii) *desirability*, which breaches the barriers of audiences' attention; iii) *accessibility*, which strives for easily understood codes of interpretation; and iv) *participation*, which is the ability to involve passers-by in discursive activities (Borghini, Visconti, Anderson and Sherry, 2010). As such, street art is never forced upon the audience; people do not have to buy a ticket to access, or consult a catalogue to understand the underlying meaning. Street art is available whenever the audience wishes to engage with it, and as such aims to overcome the feelings of elitism (Banksy, 2005). For example, street artist Banksy's stencil technique is easy replicable. His visual language appears to be desirable and is also immediately understandable for a large audience, while his absurd use of humor provokes participation and interpretation of the issue he is addressing.

In public visualization, this strategy addressed the need to address a large and maybe uninterested audience. For instance, the medium of *projection bombing* allowed our public visualization to be *i) replicable*, as it can be repeated on different surfaces in the same neighborhood, and as such reach more people. Also, the medium had a certain entertaining value, which makes it *ii) desirable* for an audience to experience. An outdoor projection is not commonly seen, as it is mostly deployed during special events, such as urban lighting festivals. In addition, the projected visualization was designed to be *iii) accessible* and easy-to-understand by using a familiar type of visualization, namely a starburst graph, which can also be found in newspapers or television news. The addition of animated transitions suggests how to the visualization should be read, while the animated quotes encouraged onlookers to interpret the visualized issue and formulate their own reaction on the issue. Furthermore, the everyday environment creates the opportunity for passers-by to *iv) participate* in the visualized topic in terms of discussing it with friends or other passers-by. All these design choices contribute to whether a person will engage with a public visualization or not.

Deliberately creating situations to publicly display information in an unobtrusive yet noticeable way, allows passers-by to approach the visualization in a wide range of opportunistic ways. It is this freedom of interacting and engaging with a visualization that can lead to public acceptance and ownership, and encourage meaningful conversations and social discussions about the issue.

### Playfulness

As a direct derivative of graffiti art, street art often transforms landscapes in a 'cartoonified' way in order to mix the serious with the humorous (Borghini, Visconti, Anderson and Sherry, 2010). Through the use of bright colors and recognizable forms and shapes – which are in contrast with the everyday grey urban backdrop - many street artworks are able to catch the attention of passers-by. The growth of street art styles and themes has brought diversity - as it is no longer limited to cartoon metaphors – yet the movement is still characterized by a playful-like approach. For example, the work of Cirugeda concerns implanting large and familiar urban furniture, such as trashcans or containers, yet he succeeds to design them in such a way that they slightly deviate from existing urban conventions, e.g. by adding 'legs' (Santiago, 2005). A playful approach does not mean the intended message cannot be critical; it imparts a fresh, positive look of the environment that helps engage public attention.

This strategy will mostly influence the intrinsic design of a public visualization. The playfulness of a visual design should be considered according to the environment context. For example, *Sight on local data* deployed a telescope metaphor, which is a typical instrument for observing the outdoors. In a museum context, the physical appearance (i.e. white, clean, wooden legs) of this installation would not look out of the ordinary. However, in the urban environment, the installation stands out and draws the curiosity of passers-by. Once the attention is grabbed, the actual interaction between a passer-by and the visualization occurs in a playful way. For instance, the tangible concept of grabbing data and putting them into slots was unusual and intriguing, while its openness encouraged people to investigate and reason about otherwise complex and boring data statistics.

Playful metaphors, ironic codes or other humorous visual design strategies can draw attention, and engage an audience. The playful approach can be implemented in various ways, such as the choice of data, the visual representation, the way of interacting etc. or a combination of the above.

### Manipulating existing meanings

The third strategy challenges the meanings that are given to everyday objects in public space. For example, trivial urban elements as asphalt can become a striking information carrier (Bird and Rogers, 2010), or a trash can turn into a skate ramp (Santiago, 2005). Street art emphasizes the unexpected opportunities that arise from urban environments, i.e. often forgotten, invisible media, to make noticeable, add surprise or elicit curiosity. Thereby, street art tends to disrupt familiar conditions to encourage citizens to explore new interpretations, meanings and opportunities. For example in 2005, urban art and design collective *Rebar* turned an existing parking space into a temporary park - complete with grass, picnic blankets and chairs - in order to question the existing meaning of public spaces, and in extent, question the political conditions on the freedom of using public space (Rebar, 2005).

Deploying this strategy for a public visualization can trigger initial curiosity and sustained interest. In *Street Infographics*, passers-by noticed how something within their familiar environment had changed (i.e. an enlarged street sign), which attracted their attention and made them curious (Claes and Vande Moere, 2013). Furthermore, the strategy can also be used as a means to seize the existing environment as an additional, situated layer of information. This way, the design of a visualization can be simplified by deleting excess information, such as specific data dimensions, legends or data sources. In *Street Infographics*, the installation did not explicitly state in what context the data should be interpreted, yet the well-considered placement of the signs on multiple locations clarified this. However, some onlookers also questioned the intentions of the signs; whether it was an act of propaganda, an artistic expression or governmental communication (Claes and Vande Moere, 2013). The ambiguous design approach encouraged people to interpret the information, reflect upon the issues and form their own opinion on them. After all, well-considered ambiguous design has the power to empower people to actively participate in the sense making (Gaver, Beaver and Benford, 2003).

The manipulation of existing meanings is a rhetoric strategy that exploits the presence of familiar yet often unconventional media, such as those commonly available in the environment, in order to be noticed and trigger curiosity. Secondly, this strategy encourages users to reflect upon the underlying meanings of known elements, which can add an additional layer of interpretation to the visualization. Therefore, manipulating existing meanings with the situated representation of information can stimulate critical views or question common interpretations.

### Ambiguous signs of authorship

Due to its illegal character, street art is often anonymous. However, some street artists recognize each other's style in order to identify authors. Banksy, for example, has been credited for a number of pieces, yet he never signed them. The ambiguous nature of ownership of street art pushed the pieces to be 'really' public, i.e. as art that is not owned or claimed by anyone but offered to the public at large to own and even appropriate it, of the art itself as well as the message it conveys.

Rather than focusing on or identifying the author – or designer – public visualization should be concerned about presenting the data source as objectively as possible (Hullman and Diakopoulos, 2011). Such data provenance strategies can include the citing and/or linking of data sources, additional references, methodological or statistical choices, as well as annotating exceptions or eventual corrections. In *Street Infographics*, we made the deliberate choice to partly obscure the information source, which was stated at the back of the signs. Yet the particular placement of the visualization, i.e. the connection to an existing, official street sign, established trust (as illustrated by one onlooker: "*it must be true, it is part of the street sign!")* (Claes and Vande Moere, 2013). This ambiguity of authorship and data source impels people to question the actual truth and reflect on the issues at stake (Gaver, Beaver and Benford, 2003).

Presenting additional information such as authorship or data origin in an ambiguous way can cause users to question the reliability and purpose of a public visualization. Yet ambiguity also has the potential to encourage deeper, more critical reflection of the information shown, and encourages various degrees of trust and re-appropriation. However, in contrast to street art, the practice of information visualization is based on objectivity and credibility, which it should respect first and foremost. Therefore, ambiguity in public visualization can also be reached by relating to interpretable, contextual elements, such as location (e.g. official signage), staging (e.g. multiple visualizations at different locations), timing (e.g. election time), or social setting (e.g. poor neighbourhood versus rich).

## Lessons learned

Based on our past experience, we list some contextual challenges for the design of public visualization. As demonstrated in this paper, these challenges can also open up rich possibilities for designers to work with.

*Reliability*. A public visualization will be considered to be objective, which necessitates an ethical responsibility towards the public. Notably, the natural perception of objectiveness can also be abused (e.g. for propaganda).

*Location*. The location of a public visualization, impacts its meaning. As such, a general approach for widely spread public visualizations seems challenging.

*Timing*. The environment is exposed to all sorts of alterations, ranging from environmental, political or cultural conditions, over infrastructure works to public manifestations, which all potentially impact how a public visualization can be interpreted.

## Conclusion

The contextual environment, which is inherently partly unpredictable, naturally impacts the engagement and interpretation of a public visualization. In this paper, we have drawn parallels with rhetoric strategies used in street art, in order to explore how to integrate and even mash the environment as an intrinsic component of a public visualization. The rhetoric strategy of *information access* creates opportunities to allow people to engage with the information in various degrees (or not). *Playfulness*, as rhetoric strategy in the everyday environment, draws attention and encourages people to interact with the information, potentially in a sustainable way. The rhetoric strategy of *manipulating existing meanings* entices people to interpret the visualization in close relationship to its immediate environment, which in itself provides for a rich, contextual situation. And finally, the rhetoric of *ambiguous signs of authorship* impels people to question the relevance, reliability and purpose of the information for themselves, allowing for various degrees of re-appropriation. In conclusion, we thus propose the surrounding environment as a powerful yet still largely untapped contextual medium for public visualization.

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